A BASELINE SURVEY OF WATER QUALITY, INVERTEBRATES, FISHERIES AND SOCIOECONOMICS ON LAKE EDWARD FOR PROPOSED SEISMIC SURVEYS IN BLOCK 4B

Final Report

Prepared for Opportunities for Environmental Planning (OPEP) CONSULT LTD by the National Fisheries Resources Research Institute (NaFIRRI)

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Seismic surveys are the main tool used by the oil industry in locating hydrocarbon accumulations. The need to discover new hydrocarbon deposits has led to widespread use of air guns as a method of seismic prospecting. Basically, the system operates as a large echo-sounder. A strong sound pulse is sent out from the seismic source towed behind the survey vessel. The high frequency noise when transmitted through a water body can lead to acoustic disturbance and may have an impact on aquatic organisms. As a result, several countries in Europe as well as the US have developed guidelines and conducted research for evaluating the impact of seismic prospecting on marine life based on baseline information on aquatic ecosystems. In Uganda, seismic surveys are relatively recent and generally, aquatic ecosystems (e.g Lake Edward that is targeted) have not yet fully been studied.

Seismic surveys have been in use since 1950s, initially with chemical explosives as the sound source. Water guns depend on the release of water at great speed creating a void in the surrounding water. Marine loudspeakers or vibrators are another source of sound in seismic surveys. Based on literature searches indicating adverse environmental impacts of these devices especially the chemical explosives, it is assumed in this assessment air guns operated through an array rump-up period (i.e. slow build-up) will be the prospecting method in the seismic survey.

Lake Edward (surface area: 2325 km^2; average depth 17 m; maximum depth: 112 m) is located in the western Great Rift valley at an altitude of 920m ASL. 29% of the lake surface is in Uganda and 71% in the Democratic Republic of Congo. The lake's major inflows are the Nyamusagari River from the southwest and the Ishasha, Rutshuru and Bwindi rivers from the south. The lake is connected to Lake George by the 36km long Kazinga channel but as the two lakes are at nearly the same level, net water transport to Lake Edward is considered insignificant. Lake Edward drains towards Lake Albert via the Semiliki River which has a series of rapids. Lake Edward experiences prolonged stratification and anoxic conditions below 80m even though anoxic conditions may sometimes occur at depth 30m and are associated with generally high concentrations of H_2S. With surface temperatures of about 25^0c, high evaporation rates and conductivity above 920µcm^{-1}, Lake Edward's water level and chemistry are sensitive to rainfall (average: 900mmyr^{-1}) variability. Lake Edward supports commercial fisheries in Uganda. The fisheries are an important source of food, livelihood and income to residents in the immediate vicinity of the lake shores and to urban dwellers in western and central Uganda. The commercial fisheries are dominated by *Oreochromis niloticus* (the Nile tilapia), Bagrus docmak (catfish/semutundu), *Protopterus aethiopicus* (lung fish) and *Clarias gariepinus* (mud fish). However, the over 50 other species of fish, mostly the haplochromines cichlids (nkejje) dominate the fish biomass.

Dominion Uganda Ltd entered into a Production Sharing Agreement (PSA) with the Government of Uganda, and acquired a license to explore for oil and gas in Block 4B located in the districts of Bushenyi, Rukungiri and Kanungu in southwestern Uganda. The Project area includes virtually the entire part of Lake Edward. 2D in Uganda Seismic surveys to be carried out in the Petroleum Exploitation Area require an EIA study that will assess, identify and evaluate the likely biophysical, socio-cultural and economic impacts of the seismic surveys.

The National Fisheries Resources Research Institute (NaFIRRI) on behalf of OPEP Consult Ltd undertook a baseline survey of the Transition Zone (basically along the shoreline) and near shore habitats of the Uganda apart of Lake Edward and Kazinga channel during December 2007 to January 2008. A major objective of the baseline survey was to generate baseline information on the aquatic ecosystem features related to the fisheries and socio-economics of the fish catch including issues raised by residents in the fish landing sites. Therefore, the baseline survey captured information on water quality, the aquatic invertebrate fauna, aspects of fish biology and ecology, the fish catch including facilities at fish landings, value in the catch and related fisheries socio-economic issues perceived by residents in the settled areas along the shores.

In order to generate the required data, field studies were carried out between 5th to10th January 2008. Four fishing villages (Kazinga, Katwe, Kishenyi and Rwenshama) were the main bases for collection of samples relevant to water quality (e.g. dissolved oxygen, water temperature, pH, water conductivity, nutrients, phytoplankton), invertebrates (both micro- and macro-invertebrates), fish biology and ecology (fish specimens), and fish catch (based on fish landed each day by fishing units). In addition to samples taken from the Transition Zone (Tz), additional samples were taken from offshore in water depth between 15m and 25m. Alongside the field measurements, residents were consulted on issues of concern related to seismic activity and their expectations. In all cases, Standard Operating Procedures, Tools and Methodologies for biophysical and socio-economic assessments were implemented in addition to literature reviews availed by the NaFIRRI Data center's electronic databases. Field samples were transported to NaFIRRI laboratories and appropriately analysed as detailed in the different sections of this Report which provides Results, Discussion and Conclusions from the study; these areas are the basis of the recommendations made for consideration in the EIA Report.

Results of the study suggest that the water quality and productivity mechanisms in Lake Edward have remained fairly stable over time. This implies that there have not been major shifts in nutrient fluxes, phytoplankton species composition or production as chlorophyll-a nor in the general water balance. For example, the dissolved oxygen content (6.84-7.79mgl^{-1}), pH (8.8-9.1), conductivity (920-939µscm^{-1}) were within range of historical data. There were few comparable data sources on phytoplankton, zooplankton and macro-invertebrates to suggest systematic historical trends and the present data can be considered as the baseline conditions among indicators of components in the food chains/food web of Lake Edward. Electronic data searches did not show known impacts of seismic prospecting on water quality components or on macro-invertebrates (e.g. shrimps). However, it is to be recognized that most of the reported seismic prospecting has been carried out in far much deeper (x15 m) water than the maximum 112m depth (close to the DRC border) in Lake Albert. Therefore, among the anticipated impacts of seismic surveys on water quality are those arising due to the relatively shallow nature of the lake. These could arise from operations of equipment and accessories in shallow water.

Fishery survey results were of three categories: from the view point of aspects of fish biology and ecology, results of experimental gill net surveys revealed the following patterns:
Haplochromine cichlids (nkejje) were the most numerous (96%) and contributed the largest biomass (76%) of all the fish retained in gill nets. The commercially exploited larger fishes (*Bagrus docmak*/"Semutundu", *Barbus altianalis*/"Kisinja", *Clarias gariepinus*/"catfish", Nile tilapia and lung fish contributed 24% to the gill net catches by weight. However, *Bagrus docmak* and Nile tilapia where mostly in the juvenile category of size class. Fish diversity was related to habitat type with the wetland-dominated Rwenshama site providing the highest Diversity Index (2.03) with Kazinga (0.56) recording the lowest Index primarily due to a dominance (89%) at this sit of one type of haplochromine (*Euterochromis nigripinnis*). However, diversity increased from the shoreline at this site out towards open water.

Through their lateral line organs, fish tend to readily detect acoustic signals and respond by moving away. Therefore it is considered that an effective mitigation measure with respect to seismic survey is to avoid areas such as the Rwenshama site (high diversity, breeding, nursery and feeding grounds) and Kazinga (high concentration of one type of fish). In addition, other measures such as seasonal closure to seismic surveys (fish breeding season) should be considered in the surveys. It was not possible during the one-off concluded fishery survey to define the fish breeding seasons in Lake Edward but may be considered to correspond to the two rainy seasons in the area (i.e. March to May, and October to November). Some of the fishes in the commercial fishery (*Barbus altianalis* and *Clarias gariepinus*) are anadromous i.e they move upstream into rivers and streams to breed while others such as the Nile tilapia and lungfish breed in the shallow (<4m deep) swampy margins of the lake, areas that also need to be excluded from the high frequency noise produced from seismic equipment. An additiona factor to consider is that habitat restricted adult species among them haplochromines in vegetation and rocky habitats would flee their habitats and become exposed to predation and fishing during seismic surveys. It may also be recommended that other acoustic techniques could be used to detect fish concentrations prior to determining the timing of a slow-build up (air gun array ramp-up) period of high frequency signals in other habitats.

During the baseline fisheries survey of December 2006 and January 2008, 302 fishing boats were found operating from the five Lake Edward landing sites in Uganda. The majority of the fishing boats (85%) used gill-nets which renders fishers using this method, the most likely to be affected by acoustic disturbance to fish. Similarly, the most affected gill net fishers would be those operating from Katwe (33%) followed by Rwenshama (28%) even though it appears that gill nets effort was well distributed in all landing sites. In terms of catch rates (quantity of fish in kg per boat per night, the sampled landing sites showed species-specific catch rate differences with Katwe dominated by gill-net caught *Bagrus dockmak* ($\approx$ 5kg.d^{-1}.boat^{-1}) and long-line caught lung fish (9.5kg.d^{-1}.boat^{-1}). Kishenyi appeared to have good returns from both gill-net (11.5kg of Nile tilapia/day/boat) and long-line (14.3kg lungfish/day/boat) even though the largest long-line catch recorded in a day from a single boat was 81.5kg at Kazinga The observed catch rates point to a concentration of fishermen in near-shore habitats and near rocky areas, habitats that are frequented by the recorded species, and which should be subjected to a real closure to seismic activity with the highest priority of attention pegged on areas with the highest catch rates of all fishing gears in the order: Rwenshama>Kisheny>Kazinga>Katwe.

The total fish catch at the four landing sites for the month of January 2008 was estimated at 108t with the highest contribution to the month's catch coming from Rwenshama (30%) followed by Kazinga (24%) and Kishenyi (22%). The gross value of the catch at the beaches (ug sh 91m) followed the same distribution patterns with Rwenshama accounting for at least 30%. These figures are based on a day's sample of the catch and value at each of the landing sites. It is essential to recognize that seasonality of catch and value, weather and phase of the moon are factors that need to be incorporated to generate more robust estimates of catch and value. Moreover, no account of fish trade with the DRC is incorporated in the analyses. Still, when fishing is estimated to occur at least for five days per weak throughout the year, the annual catch and value for Lake Edward is quite high for the number of fishers in the lake and the immediate dependants including boat and gear owners as well as their families.

Other socio-economic issues that may impact the fishers and fishing enterprises as a result of seismic prospecting were captured through Focus Group Discussions (FGDs) at four landing sites (Kazinga, Katwe, Kishenyi and Rwenshama) based on people's perceptions of what was explained as seismic activity and their concerns fish stocks and livelihood expectations (Appendix 1). In total there were 45 persons involved in the FGDs (Appendix 2). The FGDs were strengthened by Key Informant Interviews with Local Councils (LC) officials (I to III), Beach Management Units (BMU) officials including their chairpersons and data recorders. Information content was analysed to derive key issues/concerns and desires expressed. There were at least 12 key informants directly involved with the fisheries sector and with governance issues from each of the sampled sites.

The estimated Ug sh. 91m earned at the sampled landings during the moth of January 2008 probably represents a small fraction of the socio-economic importance of the fisheries of Lake Edward. Apart from fishing, other directly associated enterprises at the lake shore include fish processing, sale and repair of fishing gears and crafts, food vending and diverse commodities that feed the fisheries enterprises. There are thus found at the landing sites a wide range of activities and facilities that service not only the fisher folk but also others going to or through the landing sites. Although a verbation account and content analysis of stakeholder perceptions of seismic activities is outlined in the annexes to this report, it was noted that fisher folk related seismic prospecting to "tycooning", a fishing technique associated with beating the surface of the water with wooden clubs so as to excite fish activity and capture.

Livelihood dependence on fish and fishery activities for food and income were key issues to the majority (>70%) of responses who also emphasized the need for enforcement of fisheries laws. However, fishers were generally aware of the existence of oil-related activities and the likely presence of oil reserves based on past occasional sightings of oily substances on the lake with the expressed concern that oil exploitations was not likely to benefit the fishers and others in the fishing business as they would be forced to move away from the fish landings and from the lake resulting into loss of livelihood.

Among the key Informants the main concern and related issues captured from content analysis were:

1. Seismic prospecting was expected to lead to displacement of fisher communities and would affect most severely those who had nowhere to go,
2. There were limited opportunities on land as most of the land area is located in a National park,
3. The need to sensitize all stakeholders on the real negative impacts of seismic activities that are associated with explosions and vibrations that could lead to a disappearance of fish
4. Implementation of mitigation measures for the affected communities based on results of the EIA
5. Provision of information to stakeholders regarding each step undertaken during the seismic activity and how it could impact fish stocks, fishing and alleviation of impacts associated with the activity
6. Ensuring access to fishing and equal alternatives livelihood for the affected communities

This Report is presented in such a way as to illustrate the current state of knowledge of the aquatic system and the fisheries of Lake Edward in the Uganda part. The Report thus provides baseline information that was requested for by OPEP Consults Ltd. Following from the Introduction, the Objectives of the Assignment, the Study Area and Sampling Sites are described. The Study Methods section details Standard Operating Procedures used in water quality and related environmental assessments as well as standard methods used in fisheries surveys. Under the Chapter Results and Discussions, the different aspects investigated are dealt with and contain Conclusions and Recommendations related to the different aspects i.e. Water Quality, Invertebrates fauna, Fish Biology and Ecology, Fish Catch Assessment and Socio-economics of catch. Appendix 1 captures issues raised by the fisher communities including the perceived impacts of seismic surveys and suggested mitigation. The next appendix 2 is a list of stakeholders that contributed to the input. The last appendix 3 is a list of participating scientists and their areas of specialization.

1.0 INTRODUCTION

Seismic is derived from Greek word meaning earthquake. The need to discover new hydrocarbon deposits has led to widespread use of air-guns to become a very method of seismic prospecting. Seismic surveys are the main tool used by the oil industry and gas industry in exploration of petroleum resources by identifying precisely the character of prospective oil-bearing strata of the earth beneath sea floor, so that the oil bearing sediments can be pinpointed. Reservoirs can them be mapped accurately and drilling targets clearly established (Peterson, 2004). The surveys deploy large specialized vessels towing powerful air gun arrays that produce loud sounds to test subsurface structures. The high frequency noise when transmitted through a water body can lead to acoustic disturbance and may have the potential to impact on aquatic organisms. As a result, several countries in Europe as well as the US have developed guidelines and conducted research for evaluating the impact of seismic prospecting on marine life based on baseline information on aquatic ecosystems. In Uganda, seismic surveys are relatively recent and generally, aquatic ecosystems (e.g Lake Edward that is targeted) have not yet fully been studied.

Seismic surveys have been in use since 1950s, initially with chemical explosives as the sound source. The use of explosives as an energy source was later abandoned because of undesirable impacts on aquatic organisms and hazards to the shipping and personnel. Water guns depend on the release of water at great speed creating a void in the surrounding water. Marine loudspeakers or vibrators are another source of sound in seismic surveys. Based on literature searches indicating adverse environmental impacts of these devices especially the chemical explosives, it is assumed in this assessment air guns operated through an array rump-up period (i.e. slow build-up) will be the prospecting method in the seismic survey.

Lake Edward shared between Uganda (29%) and the Democratic Republic of Congo (71%) is located in the western Great Rift Valley at an elevation of 920m above sea level, with its northern shores a few kilometers south of the Equator ($0^0$20'S $29^0$36'E). Lake Edward is 77 km long and 40 km wide at its maximum points and covers an area of 2325 km^2 with an average depth of 17 m and maximum depth of 112 m which is about 3.5 km from the western (Congo) shore (Beadle, 1932; 1966). The lake's major inflows are from the Nyamugasani River which drains the southwestern end of the Rwenzori Mountains, and the Ishasha, Rutshuru and the Bwindi rivers which drain the Kigezi and Rwanda highlands and Virunga volcanoes in the south. A unique feature of the water shed of Lake Edward is its connection to Lake George, a shallow basin attached to Lake Edward through the 36 Km Kazinga Channel (Figure 1). Flow through Kazinga Channel is barely measurable, because the two lakes are at nearly the same elevation, although net transport is towards Lake Edward (Beadle, 1981). According to Beadle (1966), the annual contribution of the Kazinga Channel is probably much less than the input from the Inflow Rivers. Lake Edward is presently open, draining to Lake Albert to the north via Semliki River, but water loss by evaporation currently exceeds surface outflow by about 20% (Russell, 2004). Lake Edward is also an important reservoir for tropical precipitation in the

Upper Nile Watershed (UNW), the equatorial headwaters of the main River Nile (McGlue *et al.*, 2006)

Hydrological data from several expeditions on Lake Edward have demonstrated prolonged stratification and water without oxygen (anoxia) below about 80 m (Beadle, 1932; Damas, 1937; Verbeke, 1857; Beadle, 1966), although the position of the oxycline varies and anoxic bottom waters have been measured at depths as low as 30m (Beadle 1981; Hecky & Degens, 1973). Lake Edward water however has a higher concentration of H_2S in the oxygen free water associated with a lower redox potential. The annual temperature near Lake Edward is ~ 25^0C. As a result of high evaporation rates, Lake Edward's water level and chemistry are extremely sensitive to rainfall variability (Lehman, 2002). Rainfall averages ~900mm/year at the elevation of Lake Edward (Viner & Smith, 1973) and comes primarily during two rainy seasons associated with the migration of the intertropical convergence zone (ITCZ) across the equator: the "long rains" from March to May, and short rains from October to November. Instrumental weather records indicate that fluctuations in the short rains account for significantly more interannual variability than anomalies in the long rains (Nicholson, 1996). The rainfall in the Lake Edward region is strongly influenced by the Sea surface temperatures of the Indian Ocean (Russell & Johnson, 2005). The fauna of the lakes Edward and Albert are separated by a series of rapids on the Semliki River.

Most of the lake is bordered by Queen Elizabeth National Park (QENP) in Uganda and Virunga National Park in Congo. Therefore apart from landing sites which are also crossing points, the lake does not have extensive human habitation on its shores, except at Ishango (DRC) in the north, a home to a park ranger training facility. Besides Ishango, the other main settlement in DRC side in the south is Vitshumbi, while the Ugandan settlements are Mweya and Katwe in the north-east, near the Crater Lake Katwe, the chief producer of salt for Uganda. The Mweya Safari Lodge is the main tourist facility, serving both Lake Edward and Lake Katwe. The nearest cities are Kasese in Uganda to the north-east and Butembo in DR Congo, to the north-west, which are respectively about 50 km and 150 km distant by road.

The fisheries are an important source of food, livelihood and income to residents in the landing sites and to urban dwellers in western and central Uganda. The fish fauna of the lakes Edward and George is as diverse as its geological history (McClanahan & Young, 1996). The lake shares some fish species with Lake Albert and others with lakes Victoria and Kivu. Geological evidence suggests that Lake Edward has had a connection with Lake Victoria up to probably the early Pleistocene period, approximately one million years ago (McClanahan Young, 1996). Thus most of the cichlid fishes in the lakes Edward and George are similar to those of Lakes Victoria and Kivu suggesting a common ancestry. Lake Edward is home to many fish species with the commercial fisheries dominated by the Nile Tilapia (*Oreochromis niloticus*), *Bagrus docmak* (Cat fish also known locally as Semutundu), *Protopterus aethiopicus* (Lungfish) and *Clarias gariepinus* (Mudfish). The other fish species include over 50 species of the unexploited haplochromines (Nkejje) that dominate the lakes' fish biomass. Other fauna living in the vicinity of the lake include the chimpanzees, elephants, crocodiles, and lions which are protected by the national parks. The area is also home to many perennial and migratory bird species. The lake is therefore a vital asset to livelihoods of the resident communities along its shores and provides as a source of domestic water and for wild life.

Dominion Uganda Ltd has acquired a license to explore Block 4B in south western Uganda covering almost the Ugandan portion of Lake Edward in districts of Bushenyi, Rukungiri and Kanungu. As part of exploration activities in Block 4B, 2-D TZ seismic surveys will be carried out in the proposed areas. A study of the transition zone (basically along the shoreline) and near shore habitats was undertaken by National Fisheries Resources Research Institute (NaFIRRI) on behalf of Opportunities for Environmental Planning (OPEP) CONSULT LTD during December 2007 to January 2008. A major objective of the study was to carry out baseline surveys of the fisheries and water quality of the lakeshore (transition zone between land and water) between Kazinga and Rwenshama and an evaluation of the fish catch and its value in the area prior to the proposed 2-D seismic activity.

2.0. STUDY OBJECTIVE AND APPROACH

The key objective of the study was to carry out a comprehensive aquatic ecosystem baseline survey that is part of Environmental Impact Assessment of the proposed TZ 2-D seismic activity in the focus area. The study examined both the positive and negative impacts that may arise from implementation of the proposed seismic activities. The study determined and listed all potential direct and indirect environmental impacts for each of the planned activities in order to recommend and evaluate mitigation measures for adverse negative/adverse effects.

1.1 OBJECTIVES

1.1.1 Water quality

The main objective of the water quality survey was to determine the status of water quality of the Ugandan portion Lake Edward proposed for seismic activity. Therefore studies were undertaken:

a) To define physical and chemical characteristics of the waters around Kazinga and Rwenshama where the seismic activity is proposed;
b) to determine the nutrient characteristics of the waters and their relation to phytoplankton biomass as an indicator of the productivity of the waters;
c) To make some assessment of which nutrients might become deficient during phytoplankton growth as possible limiting factor for production;
d) To search for evidence of water circulation patterns that may indicate how pollutants might spread from the seismic activity areas.

1.1.2 Invertebrate fauna

The main objective of the survey of aquatic invertebrates was to determine the species composition, distribution and relative abundance of zooplankton (micro-invertebrates) and macro-invertebrate benthic communities of the Ugandan portion L. Edward proposed for seismic activity. Specific tasks undertaken were:

a) To determine the taxonomic identity of micro and macro invertebrate taxa and develop a species checklist;
b) To characterize species distribution of micro and macro invertebrates;
c) To calculate the relative abundance of micro and macro invertebrates at the selected sampling sites.

1.1.3 Aspects of fish biology and ecology

The biology and ecology of fish populations are important in monitoring their stocks and ensuring sustainable exploitation of their resources. Surveys of fish ecology provide the spatial spread of the fisheries in terms of stock densities for the exploitable and unexploited species in the aquatic system. This in turn provides information necessary to guide options for management of the ecology of these production systems and generates information necessary for management advice. For instance, knowledge about the diurnal variation in the vertical distribution of a species is essential to know which part of the stock is harvested with a particular gear at a given time.

The main objective of the fish survey therefore was to determine the importance of the Ugandan portion L. Edward proposed for seismic activity to the biology and ecology of the fishes. The following specific objectives were pursued:

a) To generate a checklist of fish species available at the time of the study in the lagoon and lake waters of the Ugandan portion L. Edward proposed for seismic activity.
b) To determine the distribution and relative abundance of the fishes in these waters.
c) To calculate catch rates of fish species common in these waters
d) To determine size (age) structures of various fish species in the area.
e) To establish biological parameters i.e. condition factor, sex ratios, size at maturity and breeding condition of the major commercial fish species.
f) To characterize the food items consumed by the commonest commercially important fish species in the area.

1.1.4 Fish catch assessment

The Catch assessment surveys were carried out to estimate the prevailing fish catch rates, total fish catches and the gross beach value of the fish catches of the local fishers at the fish landing sites on Lake Edward. The activities conducted to attain the objectives included:

a) Assembling relevant frame survey data through enumeration of all fishing crafts, their crew and fishing gears to estimate the fishing effort and generate raising factors required for the estimation of total catches from sample catch data;
b) Collection of fishery catch data including the numbers, weights, and species composition of the fish landed; and
c) Collection of information on the unit price of the catch for calculation of beach value.

1.1.5 Fisheries Socioeconomics

Fish landing sites were considered to include stakeholders who were not necessarily fishers. The views and perceptions of these groups were captured by:

a) Assessing the impact of the proposed seismic survey on the social economic issues related to the fishing business in and around Lake Edward.
b) Holding meetings with relevant fisheries stakeholders on issues related to those in a) above
c) Draw from the findings appropriate measuers that would minimize the seismic negative impacts and enhance the positive ones.

2.0 STUDY AREA AND METHODS

2.1 STUDY AREA

Lake Edward lies in an asymmetric half-graben formed during Cenozoic rifting (Ebinger, 1989). Lake Edward is oligomictic, with a semi-stable anoxia below 80 m (Hecky & Degens, 1973). The lake has a conductivity of ~900µS/cm, an average pH of 9, and a chemistry dominated by $Na+$, $K+$, $Mg2+$ and HCO^{-}_{3}.
Vegetation in the immediate vicinity of Lake Edward comprises a mosaic of East Africn evergreen bushland and thicket, secondary *Acacia* wooded grassland and farm land (Government of Uganda, 1996). Within Queen Elizabeth National Part east of the lake are dense Euphobia dawei thickets that grow in rocky areas and low-slope escarpments. To the north east are moist semi-deciduous forests in forest preserves (Kibale) and to the east (Maramagambo/Kshoya-Kitomi group) all not indicated in Figure 1. In the uplands to the north, west and south grows afromontane forest, ericaceous scrub and high montane moorland, respectively arranged with increasing elevation (White, 1983; Beuning & Russell, 2004).

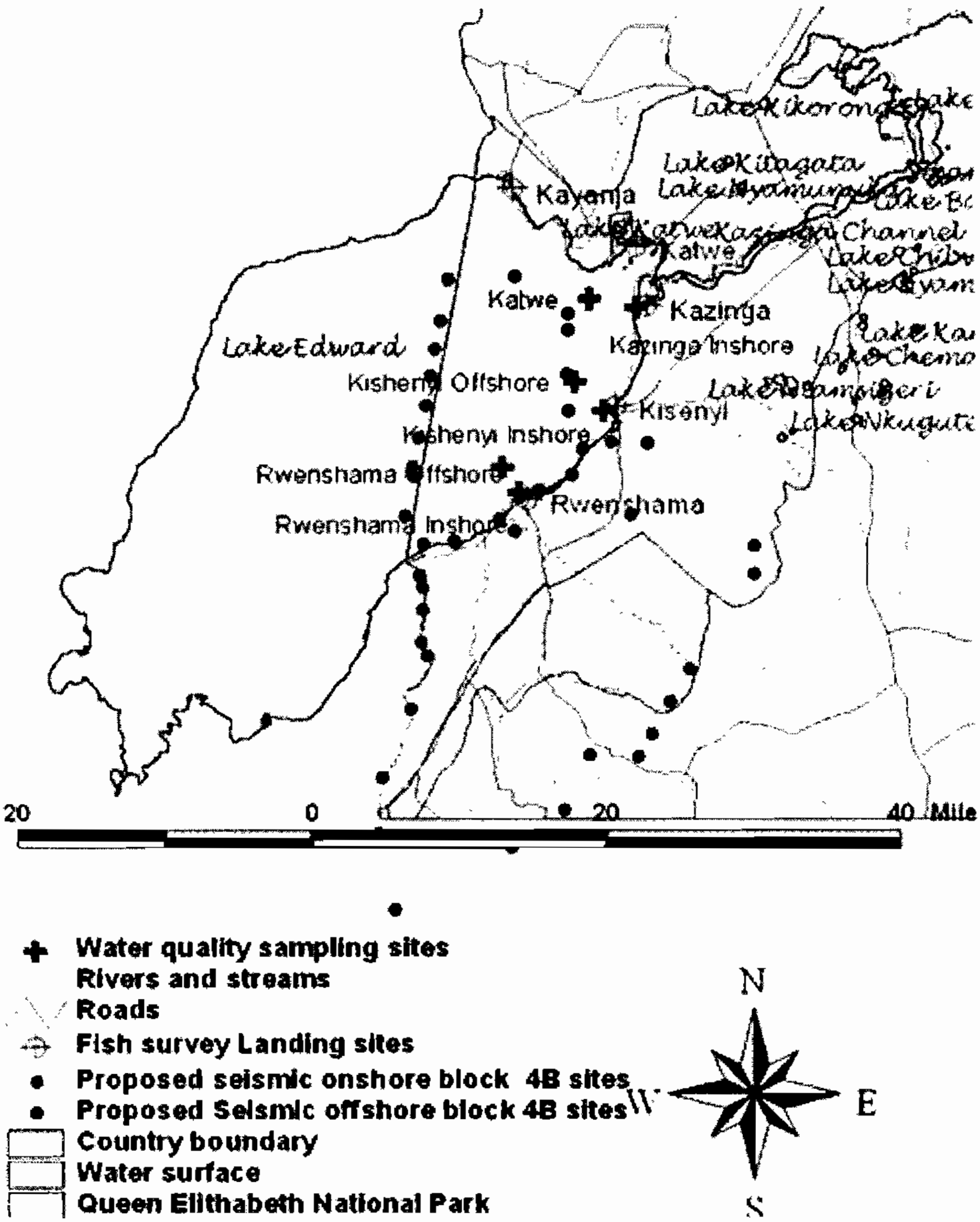

Figure 2.1 A map of Lake Edward showing the offshore and landing sites sampled in relation to the proposed seismic tests sites.

2.2 SAMPLING SITES

Both experimental fishing and water quality sampling were done in the vicinity of fishing villages (Kazinga, Katwe, Kishenyi and Rwenshama) (Figure 2.1) so as to cover the inshore and offshore waters close to areas of proposed seismic activity. The Ugandan part of Lake Edward is in the Queen Elizabeth National Park where human settlements are controlled and as a result, there are only five landing sites on the Ugandan part i.e. Kayanja and Katwe in Kasese district; Kazinga and Kishenyi in Bushenyi district; and Rwenshama in Rukungiri district. Catch assessment sampling was conducted at four of the five landing sites close/within the area designated for seismic surveys leaving out Kayanja landing site. Only one frame survey data were recorded for Kayanja landing site.

Selection of the sampling sites for census, biological and ecological analysis was based on the three major habitat types present in the lake. Kazinga site was characterised by savannah woody vegetation, a thin strip of marshy vegetation and was associated with Kazinga channel that connects Lake Edward and George. Rwenshama shoreline was characterised by a thick papyrus wetland and associated with rivers Nchwera and Ntungwa rivers emptying into the lake through the swamp. Offshore waters of Kishenyi were selected specifically to represent open water habitats. The selected habitats represent the three major habitats that characterise Lake Edward for the limited duration of the survey.

Table 2.2.1 Location, depths and bottom types of sampled stations on Lake Edward January 2008.

Station	Latitude	Longitude	Depth (m)	Bottom type
Kazinga Inshore	-0.209917	29.883950	3.4	Grey silt mud with some plant debris
Katwe	-0.201600	29.837950	8.7	Light brown organic mud
Kishenyi Inshore	-0.315633	29.851517	6	Black fine gravel with (mostly) empty shells)
Kishenyi Offshore	-0.285733	29.822767	15	Very fine brown organic material
Rwenshama Inshore	-0.397333	29.767467	7.7	Rocky bottom
Rwenshama Offshore	-0.371200	29.750600	23.4	Very fine brown organic material

2.3 STUDY METHODS

2.3.1 Water quality

a) Sampling methods

Physical variables namely: dissolved oxygen (mg L^{-1}), temperature (^{o}C), pH and water conductivity (µs cm^{-1}) were measured *in situ* using portable meters (Wagtech 983-030, WTW PH330 and HI 9033 multi-range). The meters were calibrated with standard solutions before use. Water transparency and depth (m) were measured using standard secchi disc and echo sounder, respectively. The variables were measured as depth profiles at the three lake sampling sites. Variables in the shallow areas were measured only at surface and bottom positions of the water column due to shallow depth.

b) Sample analysis

Water samples for analyses of major dissolved chemical constituents (salts, total suspended solids, nutrients (e.g TN and TP) and phytoplankton biomass as chlorophyll a (chl a), were collected using a Van Dorn sampler. Water samples were collected from 1 m below the water surface and above the bottom sediment at the deeper lake sampling sites and only at mid-water depth at the lagoon sites. Water was transferred from the Van Dorn sampler to clean plastic sample bottles and placed in cool boxes containing ice blocks. Some of the water samples were filtered using Whatman GFC filter papers (47 mm, pore size 0.7µm). The filter papers were gently folded using fine forceps and covered in Petri dishes containing silica gel. The dishes were wrapped with aluminum foil to keep the papers in the dark. Papers were taken for extraction of chl a at NaFIRRI, Jinja.

Extraction for chlorophyll a (Chl a) from the filter papers was conducted at NaFIRRI laboratory following the standard analytical methods of freshwaters (Stainton *et al.*, 1977). Analyses for concentrations of total nitrogen and phosphorus (TN, TP) and soluble Reactive Silica (SRSi) were conducted following the methods of Stainton *et al.* (1977).

To determine algal species composition, 20 mls of the unfiltered water sample were transferred to glass scintillation vials to which Lugol's solution was added. Algal total biomass determination in the laboratory was done using an inverted microscope at 400X magnification

Data analysis

The physical variables (dissolved oxygen, temperature, pH and water conductivity) at the stations were plotted as depth profiles except those of the inshore areas. Individual values of the major dissolved chemical and organic constituents, total suspended solids, nutrients, Chl a, secchi depths, are presented as tables and figures.

2.3.2 Invertebrate fauna

Zooplankton samples were collected using a conical plankton net (Nansen type) of mesh size 60 µm, with a circular mouth opening of diameter 0.25 m. Three vertical net hauls were taken at six selected sites representing both the inshore and offshore habitats (see Figure 2.1.1 and Table 2.2.1). The samples from the vertical hauls were combined to make a composite sample and put in labeled 50 ml bottles in which 4% sugar-formalin mixture was added as preservative. (Sugared formalin stops swelling of cladocerans, which would lead to taxonomic problems). In the laboratory each sample was diluted to 400 mls, agitated and a sub-sample of 10 mls taken, further diluted to 50 mls from which a series of 2, 2 and 5 ml sub-samples were taken with an automatic bulb pipette. Each sub-sample was placed in a plankton counting chamber and examined under an inverted microscope at x 40 magnification for counting anf x 200 for identification.

Macro-invertebrates samples were collected in triplicates from each of the sampling sites in the lake. The samples were collected using a ponar grab of surface area 238 cm^2 and cleaned in a washing bag of mesh size 400 µm. They were then preserved with 70% alcohol in plastic sample bottles. At NaFIRRI laboratory the invertebrate fauna were sorted, identified to the lowest taxonomic level possible and enumerated. Identification manuals of Fernando (2002) and Ruttner-Kolisko (1974) were used to identify zooplankton while Merritt & Cummins (1997), Pennak (1989) and Voshell (2002) were used for macro-invertebrates. Results were computed as number of individual organism of a given taxon per square meter. The numbers were plotted to illustrate relative abundance by taxon at each sampling site.

2.3.3 Aspects of fish biology and ecology

Overnight fishing experiments were made at the in three habitat types of Lake Edward (two inshore sites around Kazinga and Rwenshama landing site, and one open water station off Kishenyi landing site (see Figure 2.1.1). At each station, three fleets of graded multifilament gillnets of mesh sizes 1 to 5.5 inches at intervals of 0.5 inches, and 6 to 8 at one inch interval were used. While nets of mesh sizes 2" and above were of standard commercial dimensions (26 meshes deep and 90 m long), 1" and $1^1/_2$" nets were doubled to 52 meshes deep. Gillnets were all mounted at 50% hanging ratio. Three fleets of multifilament gillnets were set along the shoreline in depth of at least 3 m (inshore), 100 m from the shore (mid-shore), and 200+ m from the shore (offshore). The nets were set in the evening and retrieved the following morning.

Fish specimens were identified in the field to species as in Greenwood (1966). Specimens of fishes not easily identifiable in the field especially the haplochromines were preserved in 10% formalin for laboratory morphometric examination and eventual identification. For each species, the total count, total weight (grams) and individual lengths (cm) of the fish were recorded. Fork length (FL) and Total Length (TL) was measured for all species with forked and entire caudal fins, respectively. The fish was then cut open to determine sex, the state of gonad development and feeding regimes. Gonad maturity stages were awarded based on a 7-point scale as outlined by Bagenal & Braum (1978) and LVFO (2006). Stomachs were assessed for fullness and dissected out. Types of food items ingested were determined either directly with the naked eye in the field or microscopically in the laboratory. Quantities of food items were assessed by warding points (Hynes, 1950).

2.3.4 Fish catch assessment

Information relevant to fish catch assessment
The Fish catch assessment survey (CAS) involved the collection of information on parameters relevant to the estimation of total fishing effort, fish catch rates, fish yield and the beach value of the catches.

a) Estimation of the total fishing effort
A complete enumeration of all fishing crafts, fishers and fishing gears was carried out at the four selected landing sites. The data captured included details of the operational fishing crafts i.e. craft type, length, method of propulsion, and the number of crew; and the characteristics of the fishing gears used, i.e. the type, number, and size of fishing gear. This information was to be used to determine the raising factors of sample catches to total catches.

b) Sampling of fish catches
At each landing site, the fishing boat with fishing gears was the basic sampling unit. A random sample of active fishing boats was selected for each of the gear type in use encountered at the landing site. An attempt was made to cover as many fishing units as was practically possible. The information recorded for each sampled boat included date, type of boat, number of days the fished in the last one week, time of fishing i.e. day or night, mode of propulsion of boat (paddle or motor), number of crew, gear type, gear number and size, the number and weight of each fish species landed. The sample length of the main species was also recorded. Records of the price at which the fish catch was sold or would be sold at the fishing boat level were used to approximate the unit price (shs/kg) of different fish species at the landing site.

c) Data processing and analysis
The fishing crafts were segregated into effort groups by gear type and the CAS indicators estimated for each effort group. The essential parameters were derived as follows:

1. The mean catch rates (kg per boat per day), estimated for each effort group.
2. The total fish catches, estimated using the mean catch rates and the total effort data from the frame survey. The boat activity coefficient, i.e. the probability that a fishing boat of each gear type would be active on any day during the month, derived from the mean number of days fished in the last one week. The total catch of each effort group was then estimated.
3. The beach value of the catch i.e. the gross income to fishers was estimated by raising the estimated total catch in each effort group by the mean unit price of each fish species landed.

2.3.5. Socio-economics

Other socio-economic issues that may impact the fishers and fishing enterprises were captured through Focus Group Discussions (FGDs) at four landing sites (Kazinga, Katwe, Kishenyi and Rwenshama) based on people's perceptions of what was explained as seismic activity and their concerns forfish stocks and livelihood expectations (Appendix 1).

In total there were 45 persons involved in the FGDs (Appendix 2). The FGDs were strengthened by Key Informant Interviews with Local Councils (LC) officials (I to III), Beach Management Units (BMU) officials including their chairpersons and data recorders. Information content was analysed to derive key issues/concerns and desires expressed. There were at least 12 key informants directly involved with the fisheries sector and with governance issues from each of the sampled sites.

3.0 RESULTS AND DISCUSSIONS

The results of each component of the baseline survey namely water quality, zooplankton, macro-benthos, aspects of fish biology and ecology and catch assessment are presented and discussed separately so as to facilitate continuity from identification to discussion. Baseline information and emerging issues are then summarized in one final section of conclusions and recommendations.

3.1.1 Water Quality

Conductivity

Figure 1 shows electrical conductivity at various sampling sites. It was noted that conductivity was significantly lower in Kazinga Channel (< 241 µ*S* cm^{-1}) compared to what was determined in the lake. No significant differences in electrical conductance were noted among sites within the lake (range: 920.5 to 939.4 µ*S* cm^{-1}).

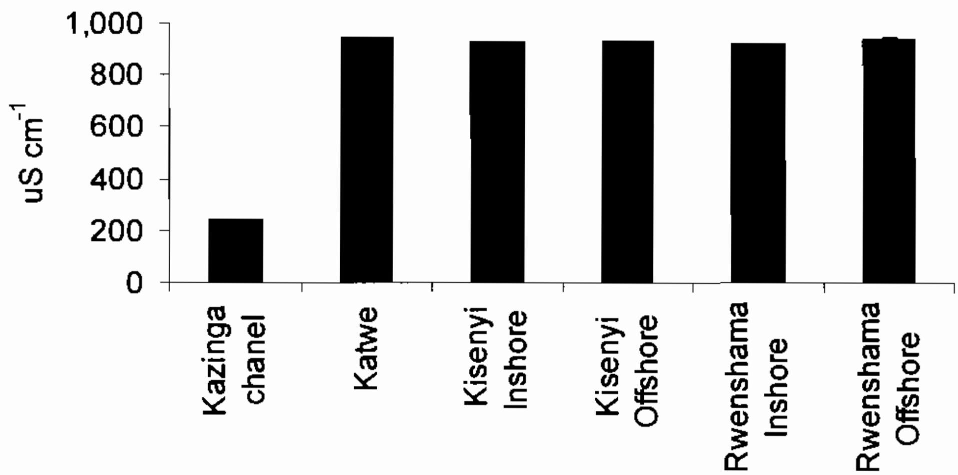

Figure 1: Electrical conductivity of Lake Edward water at various sampled sites during January 2008.

Temperature varied greatly among sites, with Kishenyi-Inshore and Offshore having relatively higher water temperatures (26.7 – 26.9 ^{o}C) compared to other stations (25.5 – 26.3 ^{o}C).

Figure 2 shows ambient dissolved oxygen and pH of the water. It was noted that the waters of Lake Edward and Kazinga Channel were well aerated and slightly alkaline

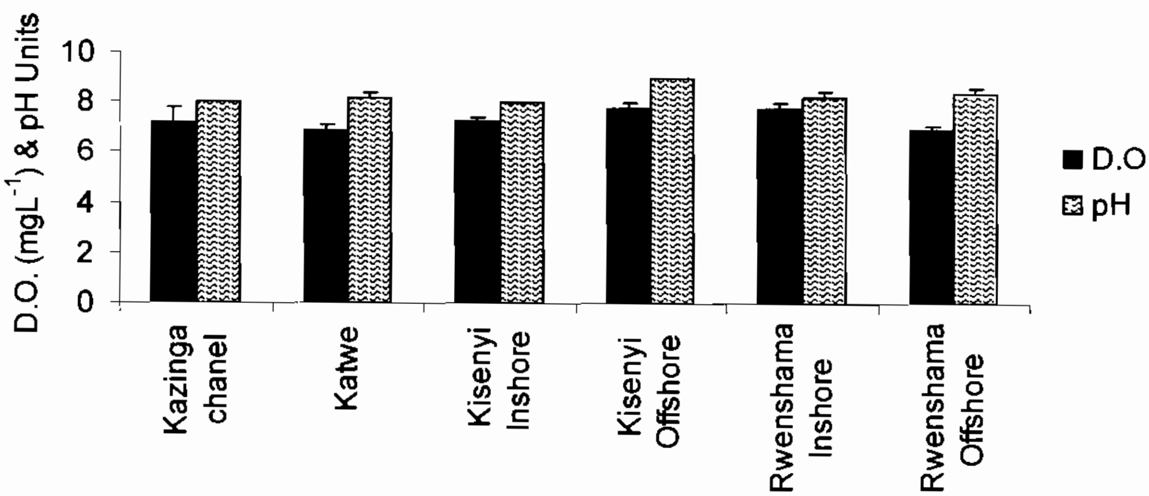

Figure 2: Water dissolved oxygen and pH from various sampled sites in Lake Edward during January 2008.

Nutrient concentrations

Significantly higher TP (159.8 μg L^{-1}) and SRSi (8,606.2 μg L^{-1}) were found in Kazinga Channel. At other sites, TP ranged between 34.2 μg L^{-1} at Katwe and 52.8 μg L^{-1} at Kishenyi-inshore, while SRSi was between 4,562.0 μg L^{-1} at Kishenyi-offshore and 5,279.0 μg L^{-1} at Rwenshama-inshore.

The concentrations of ambient bio-available macro-nutrients (N & P) are shown in Figure 5. It was noted that the concentration of NO_3-N was higher compared to other nutrients at all sites except at Rwenshama-offshore

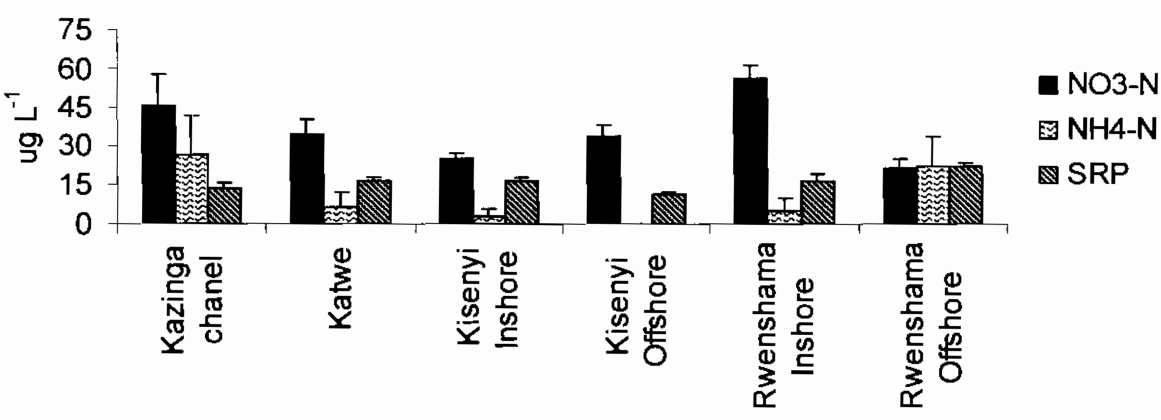

Figure 5: Concentrations of some macro-nutrients in the water at various sampled sites in Lake Edward during January 2008.

Other than in the Kazinga Channel and Rwenshama offshore, the concentration of NH_4-N was the encountered in the least concentrations (< 6.2 µg L^{-1}).
The TN:TP ratios for different sites are given in Table 2. The higher the concentration of TN, the higher the ratio. Kazinga Channel had almost double this ratio compared to other sites.

Table 2: TN: TP ratios from different sites on Lake Edward and Kazinga Channel during January 2008

Site	TN:TP Ratio
Kazinga channel	20.8
Katwe	10.6
Kishenyi Inshore	11.5
Kishenyi Offshore	11.7
Rwenshama Inshore	10.1
Rwenshama Offshore	12.0

Correlation coefficients

Correlation coefficients were determined between Chlorophyll-a concentration and some parameters i.e. SRP, NO_3-N, SRSi, dissolved oxygen and secchi depth (Table 1). There were strong positive correlations between Chl-a with SRP and SRSi, but NO_3-N showed a very weak positive correlation. Negative correlations were noted between Chl-a, and dissolved oxygen in addition to secchi depth (Table 1). Secchi depth was found to be lowest in the Kazinga Channel than at other sites, and offshore stations had relatively clearer waters compared to inshore ones.

Table 1: Correlation coefficients between Chl-a and some physico-chemical parameters

Physico-chemical parameters	**Correlation Coefficient**
Soluble Reactive Phosphorus (SRP)	0.980
Nitrate-Nitrogen (NO_3-N)	0.296
Soluble Reactive Silica (SRSi)	0.980
Dissolved Oxygen (D.O.)	-0.255
Secchi Depth	-0.648

Secchi depth was found to be lowest in the Kazinga Channel than at other sites, and offshore stations had relatively clearer waters compared to inshore ones.

Algal Species Composition

Three major taxa dominated the algal community (Table 2). These were diatoms, greens and blue-greens; others were the Cryptophytes and Dinoflagellates. Diatoms dominated in biomass at Katwe (18,826.1 µg L^{-1} or 62.6%), Kishenyi-inshore (50,546.8 µg L^{-1} or 87.2%), and at Rwenshama (3,389.6 µg L^{-1} or 71.5%). At other sites, diatoms formed less than 15% of the total algal biomass.

The biomass of blue-greens was dominant at Kishenyi-offshore (5,940.1 µg L^{-1} ~76.1%), and in Kazinga Channel (28,142.2 µg L^{-1} ~ 71.4%). At Katwe, the biomass of blue-greens was 10,888.7 µg L^{-1} ~ 36.2%, while biomass contribution by blue-greens was less that 10 % at the rest of the sites.

Green algae formed an insignificant part of the total algal biomass as their contribution was less than 10 % at all sites except in Kazinga which had 2,533.7 µg L^{-1} ~ 11.9%. The biomass of Cryptophytes was only dominant at Rwenshama-offshore (6,185.1 µg L^{-1} ~ 83.3%). No other site had Dinoflagelates except Rwenshama-inshore where they contributed 331.2 µg L^{-1} ~ 7.0% of the total algal biomass.

Figure 4 shows algal biomass as Chl-a (Figure 4a) and total biomass (Figure 4b). Chlorophyll-a, was significantly higher in Kazinga Channel than at other sites that showed no inter-site differences. Total algal biomass (Figure 4b) was highest at Kishenyi offshore followed by Kazinga Channel and Katwe, with the rest having less than 7,900 µg L^{-1}.

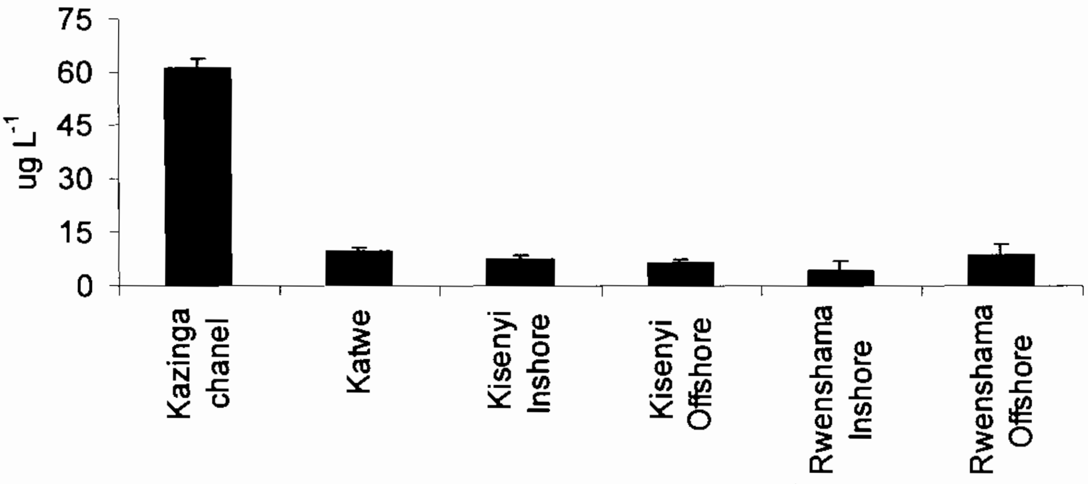

Figure 4a: Algal biomass (Chl-a) at various sampled sites in Lake Edward during January 2008.

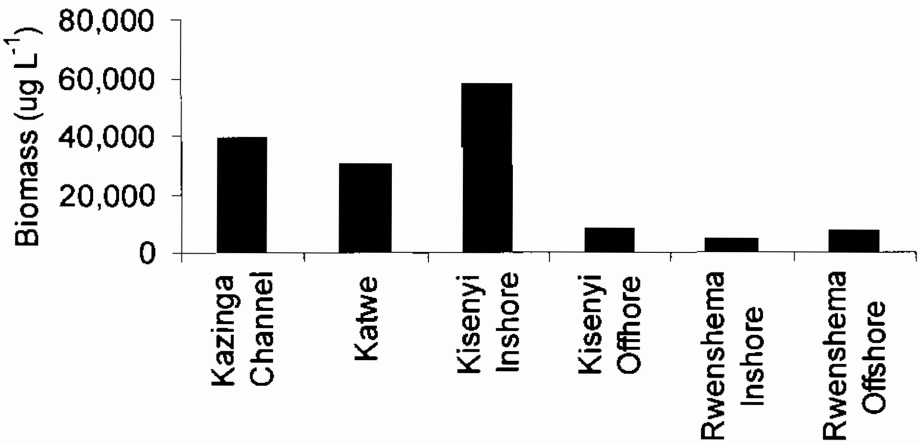

Figure 4: Total algal biomass at various sampled sites in Lake Edward during January 2008

Three major groups of algae encountered belonged to the blue-greens (Cyanophyta), green algae (Chlorophyta) and the diatoms; others were the cryptophytes and the dinoflagellates (Table 2). In ascending order of species diversity, Katwe had 23, Rwenshama with 25, Kazinga Channel with 44 and Kishenyi with 58.

Table 2: Algae species composition from sampled sites in Lake Edward and Kazinga Channel during January 2008

Taxa	Kazinga Channel	Katwe	Kishenyi	Rwenshama
Blue green algae				
Microsystis aeruginosa	P	-	P	-
Microsystis wasenbergii	P	-	P	-
Microsystis novacekii	P	P		-
Microsystis flos-aquae	P	-	P	P
Microsystis sp	-	-	P	-
Pseudanabaena	-	-	P	-
ceolomoron tropica	P	P	P	-
Aphanocapsa sp	P	P	P	P
Aphanocapsa delicatissima	P	P	P	-
Aphanocapsa holsatica	P	P	P	-
Aphanothece sp	-	-	P	-
Chroococcus limnetica	P	P	P	-
Chroococcus turgidus	P	P	P	P
Chroococcus dispersus	-	-	P	-
Cylindrospermopsis africana	P	P	P	P
Cylindrospermopsis cuspis	P	-	P	-
Cylindrospermopsis sp	-	P		-

Taxa	Kazinga Channel	Katwe	Kishenyi	Rwenshama
Cyanodictyon sp	P	-		-
Coelosphaerium kuetzingianum	P	-	P	-
Merismopedia glauca	P	P	P	-
Merismopedia tenuissima	P	-	P	P
Planktolyngbya limnetica	P	P	P	P
Planktolyngbya cirmucreta	P	P	P	P
Plankitolyngbya contorta	P	-	P	-
Planktolyngbya undulata	-	P		-
planktolyngbya tallingii	P	-	P	P
Anabeanopsis tanganyikae	P	-	P	-
Glaucospira sp	P	-		-
Romeria	P	-		-
Anabeana circinalis	-	P	P	-
Anabeana flos-quae	-	-	P	-
Romeria gracile	-	-	P	-
Green				
Scenedesmus arcutus	P	-	P	P
Scenedesum perforutus	-	P	P	-
Scenedesmus acuminatus	P	-	P	-
Scenedesmus ovalternus	P	-		-
Scenedesmus castato	-	P		-
Scendesmus quadricauda	-	P	P	P
kirchnera	P	-	P	-
Ankistrodesmus falactus	P	P	P	P
Ankistrodesmus setigera	-	-	P	-
Pediastrum tetras	P	P	P	-
Pediastrum simplex	-	-	P	-
Oosystis orbagii	P	-		-
Oosystis soliteria	-	-	P	-
Stuarustrum gracile	P	-	P	-
Monoraphidum contarta	P	-	P	P
Cosmorium depressium	-	-	P	P
Tetraedron trigonum	P	-	P	P
Tetraedron tetras	-	-	P	P
Tetraedron minimum	-	P		-
Dydimosytis	-	-	P	-
Crucigenia fenestrata	-	-	P	-
Ceolastrum reticulum	-	-	P	-
Coelastrum cambirium	P	-	P	-
Closterium acicularis	-	-	P	-
Diatoms				

Taxa	Kazinga Channel	Katwe	Kishenyi	Rwenshama
Nitszchia acicularis	P	-	P	P
Nitszchia fonticola	P	P	P	P
Navicula radiosa	P	-		P
Epithemia argus	P	P	P	-
Epithemia turgida	-	-		P
Rhapalodia uncinata	P	-		-
Surirella angustata	P	-	P	P
Cooconies	-	-	P	-
Navicula gastrum	-	-	P	-
cylostephanodiscus sp	-	-	P	P
Cyclotella sp	-	-	P	P
cylostephanodiscus astraca	-	P	P	P
Cryptophyta				
Cryptomonus	P	-		-
Cryptomonas sp	P	-	P	-
Rhodomonas minuta	-	-	P	-
Rhodomonas sp	P	-		P
Dinoflagelletes				
Glenodedinium sp	P	-		-
Peridinium sp	-	-	P	P
Total	**44**	**23**	**58**	**25**

NB: P = present; - = not encountered

Discussion

Lakes Edward and George are connected by the 30 km long Kazinga Channel, but some of their limnological characteristics were very different especially the electrical conductivity of the water. The saline nature of the waters of Lake Edward could be attributed to past geological formations. With a conductivity of more than 800 µS cm^{-1}), the ionic concentration is so high that salt deposits are found at Katwe which is one of the sites sampled. Electrical conductivity is closely correlated with total ionic concentration in the water (Talling & Talling, 1965). According to classification of lakes based on electrical conductivity, Lake Edward falls in the range 600 to 6,000 µS cm^{-1}, since it has a range of 920.2±1.2 and 939.4±1.8 µS cm^{-1}. Beadle (1932), Damas (1937), and Fish (1952) measured conductivity of 884, 1,130 and 878 µS cm^{-1} respectively. In a similar direction, Talling and Talling (1965) measured conductivity of Lake Edward in June 1961 and was 925 µS cm^{-1}. Thus, conductivity of this lake has remained fairly stable over the years hence may not be a factor in explaining any limnological changes of the lake if any has been noted. The conductivity of Lake Edward is far above that of the Kazinga Channel since waters of the channel originate from the very fresh waters of Lake George.

Given the relatively high concentrations of dissolved oxygen (range: 6.84 to 7.79 mg L^{-1}) in the surface waters, the water environment could be regarded as good for biota especially fish. The well oxygenated waters could be attributed to diurnal mixing of surface waters under the influence of strong winds that churn the waters leading to physical recharge, in addition to biological recharge through algal primary production. This argument is supported by the slightly alkaline waters (pH range: 8.0 to 9.0) which is attributed to CO_2 fixation through algal photosynthesis. Like water temperature and conductivity, the pH of Lake Edward has also remained fairly constant since data of June 1961 gives a range of 8.8 to 9.1.

One measure of algal biomass is either through chemical determination of Chlorophyll-a or total algal biomass. The short-coming with the former is that it only determines one aspect of biomass (i.e. Chl-a) and the rest of the biomass elements are not accounted for. The significantly high algal biomass (Chl-a) in the Kazinga Channel is in part attributed to the highly productive waters from Lake George, in addition to nutrient stimuli for primary production. One of the major sources of nutrients is excreta from the high population of hippos, buffalos and birds, let alone human influences. The nutrient regimes might be influencing the dominance by three major algal taxa i.e. blue-greens, greens and diatoms, with Cryptophytes and Dinoflagellates forming a small proportion. This algal species composition could also be influenced by N:P ratios that are below the conventional Redfield ratio of 16:1

Phytoplankton is important because they exist at the base of the aquatic food web and represent a large source of food for various aquatic organisms including fish. Phytoplankton directly affect global climate since they use atmospheric carbon dioxide, a greenhouse gas, during photosynthesis. The smaller the concentration of phosphorus, the higher the N:P ratio. The 16:1 Redfield ratio was used too rigidly and was regarded as the optimum ratio for algal production. This ratio is an average that is subject to change due to natural variability in the water environment. The recorded ratio for Kazinga Channel indicated a higher concentration of TN and a lower TP compared to other sites whose average ratio was below the conventional Redfield value of 16:1. A ratio that is less than 16:1 may indicate N-limitation, but this has to be verified e.g. through N-debt experiments.

The significantly high concentrations of SRSi in Kazinga Channel does not explain the low total biomass of diatoms (only 11.9%) that depend on this resource. In addition, lack of significant differences in the concentration of SRSi among sites in Lake Edward did not fully explain the variability in biomass of diatoms.

3.1.2 Invertebrate fauna

3.1.2.1 Micro-invertebrates (Zooplankton)

Composition and distribution

The community of zooplankton from the six sampled sites in Lake Edward was constituted by two broad groups of Crustacea (Cladocera or water fleas and Copepoda) and Rotifera (Table 1). Three cladoceran species, *Ceriodaphnia cornuta, Moina micrura* and *Diaphanosoma excisum*; all four copepod constituents and two rotiferans, *Keratella tropica* and *Synchaeta* exhibited cosmopolitan distribution pattern, recovered from all the six sample sites. Most rare species were rotifers and included *Asplanchna* sp., *Brachionus quadridentatus*, *B. budapestinensis, B. Calciflorus, B. plicatilis* and *Filinia longiseta*.

Table 1. Zooplankton species composition and distribution at selected sites in Lake Edward, January 2008 (Key: P is $\leq 10^3$, PP is $\leq 10^5$, PPP is $\geq 10^6$ individuals per metre square, and A is absent).

Sites	Kishenyi Inshore	Kishenyi Offshore	Kazinga Inshore	Katwe	Rwenshama Inshore	Rwenshama Offshore
Water depth (m)	5	14	2.5	8	5	22
Cladocera:						
Ceriodaphnia cornuta	P	P	P	P	P	P
Chydorus spp.	A	P	A	P	P	A
Daphnia lumholtzi	A	P	A	P	A	P
Daphnia barbata	A	A	P	A	A	P
Diaphanosoma excisum	P	P	A	P	P	P
Moina micrura	P	P	P	P	PP	P
Copepoda:	A	A	A	A	A	A
Mesocyclops sp.	P	P	P	P	P	P
Thermocyclops neglectus	PP	PP	PP	PP	PP	PP
Cyclopoid copepodite	PP	PPP	PP	PPP	PP	PPP
Nauplius larvae	PP	PPP	PPP	PP	PP	PPP
Rotifera:	A	A	A	A	A	A
Asplanchna spp.	A	A	P	A	A	A
Brachionus angularis	P	A	PP	P	P	A
Brachionus budapestinensis	A	A	P	A	A	A
Brachionus quadridentatus	A	A	A	A	A	P
Brachionus calyciflorus	A	A	P	A	A	A
Brachionus plicatilis	A	A	A	A	P	A

Sites	Kishenyi Inshore	Kishenyi Offshore	Kazinga Inshore	Katwe	Rwenshama Inshore	Rwenshama Offshore
Filinia longiseta	A	A	A	P	A	A
Filinia opoliensis	P	P	A	P	P	A
Keratella tropica	P	P	P	P	P	P
Synchaeta spp.	P	P	P	P	P	P
Trichocerca cylindrica	A	A	P	A	A	P

Species richness

Each group supported several genera and species. Cladocera had five genera (*Ceriodaphnia, Chydorus, Daphnia, Diaphanosoma* and *Moina*); Copepoda had 2 genera *Mesocyclops* and *Thermocyclops* while Rotifera had six genera (*Asplanchna, Brachionus, Filinia, Keratella, Synchaeta* and *Trichocerca*) (Table 1) . Among Cladocera, only the genus *Daphnia* had two species while the rest had one species each. Similarly, both genera of Copepoda had one species each and two growth stages (copepodites and nauplius larvae). Apart from *Brachionus* and *Filinia* which had five and two species respectively, rotiferan, the remaining genera supported a single species each.

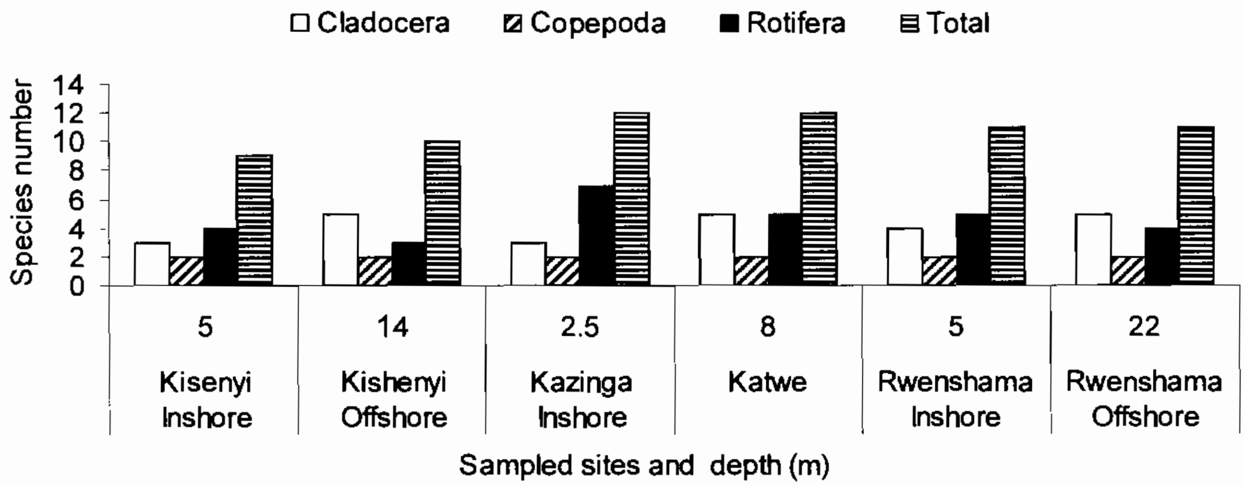

Figure1. Zooplankton species richness at selected sites in Lake Edward, January 2008.

In general, rotifers supported higher species number than copepods and cladocerans across the six sample sites (Fig 1.). The number of rotiferan and cladoceran species between sites varied within narrow limits. On the other hand, the number of copepod species between sites was constant with two species recorded at each of the six sites. The total species number was comparable at the different sample sites and ranged between 8 and 11.

Relative abundance

The two copepod species *Mesocyclops* sp. and *Thermocyclops neglectus* and their two growth stages (copepodites and nauplius larvae) constituted over 70% of the total zooplankton community in the areas of the survey in Lake Edward (Table 2). Highest copepod abundance, 96.8 and 95.8 occurred at Kishenyi and Rwenshama offshore sites respectively. Cladoceran highest relative abundance (17.1%) was recorded at Rwenshama inshore site and the lowest (1.1%) at Kazinga inshore. Rotifers had 12.3% as the highest relative abundance at Kazinga inshore and 1.0-1.8% as the lowest relative abundance at Kishenyi and Rwenshama offshore sites respectively.

Table 2. Relative abundance (%) of zooplankton broad groups at selected sites in Lake Edward, January 2008.

Zooplankton group	Kishenyi Inshore	Kishenyi Offshore	Kazinga Inshore	Katwe	Rwenshama Inshore	Rwenshama Offshore
Cladocera	7.5	1.5	1.1	7.1	17.2	3.2
Copepoda	86.5	96.8	86.6	90.5	76.4	95.8
Rotifera	6.0	1.8	12.3	2.4	6.3	1.0

Numerical abundance

Copepoda numerical abundance was noticeably higher than Cladocera and Rotifera in all the six sample sites (Fig.2). Highest copepod and total zooplankton abundance occurred at Kishenyi and Rwenshama offshore sites (> 4 million indiv. m^{-2}). The sites with lowest numerical abundance were Kishenyi, Kazinga and Rwenshama inshore. Generally, the deeper (8-22 m) offshore sites supported higher densities of zooplankton than the shallow inshore areas.

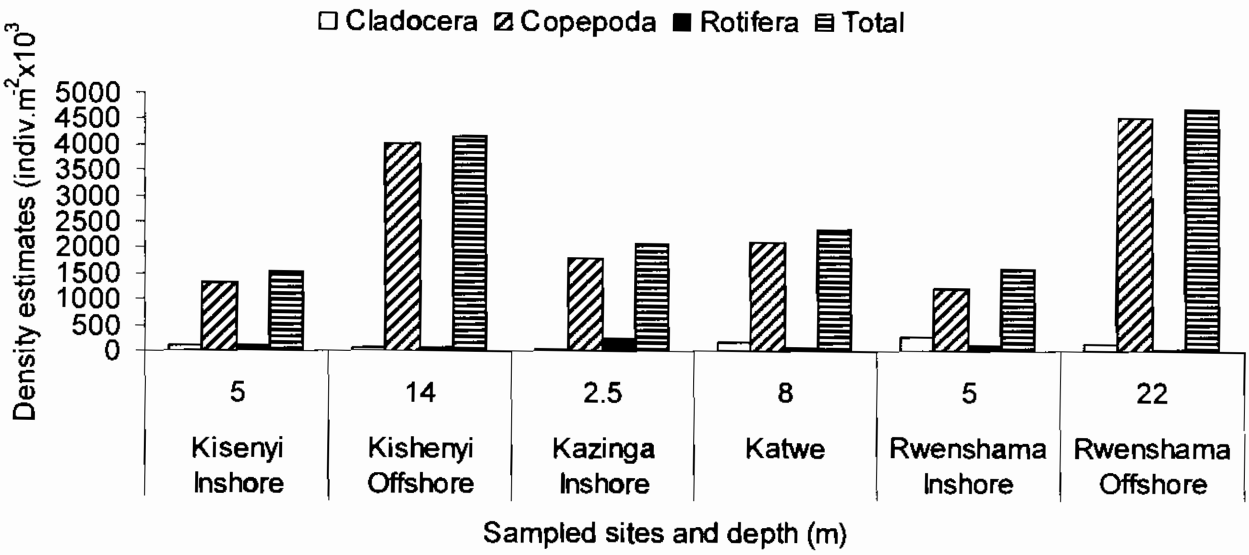

Figure 2. Zooplankton density estimates (indiv. $m^{-2}x10^3$) for selected sites in Lake Edward, January 2008.

3.1.2.2 Macro-invertebrates

Composition and distribution

The benthic (bottom dwelling) macro-invertebrate community was constituted by seven broad groups of organisms (Table 3) namely: the water snails (Gastropoda and Bivalvia), lake fly larvae (Diptera), mayfly juveniles (Ephemeroptera), dragonfly juveniles (Odonata), caddis fly larvae, (Trichoptera) and water earthworms (Oligochaeta).

Lake fly larvae and water snails (gastropods) exhibited wide distribution within the survey area, being recovered almost at all the six sample sites. Rarely occurring macro-invertebrates were *Gyraulus* sp., *Caenis* sp., Libellulidae, *Clinotanypus* and Psychomidae belonging to the water snails, mayflies, dragon flies lake flies and caddis flies respectively. These species/taxa were recovered from at most one site.

Table 3. Species composition of macro-invertebrates at six sites in Lake Edward, January 2008.

Station	Kazinga Inshore	Katwe	Kishenyi Inshore	Kishenyi Offshore	Rwashama Onshore	Rwashama Offshore
Depth(m)	3.4	8.7	6	15	7.7	23.4
Bivalvia						
Corbicula africana	A	A	A	P	P	P
Gastropoda						

Biomphalaria smithi	A	A	P	A	P	A
Gyraulus sp.	A	A	A	A	P	A
Gabbia humerosa edwardi	A	A	P	A	P	A
Melanoides t.tuberculata	P	P	P	P	P	P
Ephemeroptera						
Caenis sp.	A	A	A	A	P	A
Diptera						
Chironomus sp.	P	P	A	P	P	P
Clinotanypus sp.	P	A	A	A	A	A
Procladius sp.	P	A	P	P	A	A
Tanypus sp.	P	P	A	P	A	P
Tanytarsus sp.	A	A	P	A	P	A
Chaoborus sp.	P	P	P	P	A	P
Others(Chironominae)	A	A	P	A	P	A
Odonata						
Libellulidae	A	A	P	A	A	A
Trichoptera						
Psychomidae	A	A	A	A	P	A
Oligochaeta						
Nais sp.	P	P	P	P	A	P
No. of taxa	**7**	**5**	**9**	**7**	**10**	**6**

Species richness

In general, Diptera and gastropod groups supported relatively high number of species (up to 5) compared to other groups (Table 3). The rest of the groups were represented by a single species and showed intermittent distribution patterns. Maximum number of species (5) for dipterans was recorded at Kazinga inshore while that for gastropods occurred at Rwenshama inshore. Total species richness was highest at Rwenshama and Kishenyi inshore; 10 and 9 species respectively). The remaining sites had comparable species richness ranging between five and seven species.

Numerical abundance

The macro-benthic species (race), *Melanoides tuberculata tuberculata* was prominent at nearly all sites sampled with highest abundance at Kishenyi inshore and offshore; 336 and 280 indiv. m^{-2} respectively (Fig.3). Other gastropod species occurred at relatively low densities in all sample sites (< 100 indiv. m^{-2}).

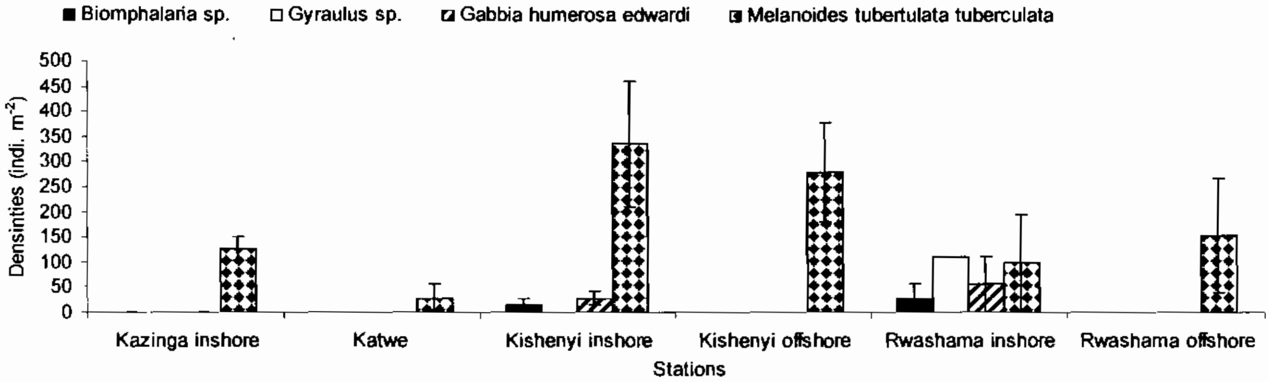

Figure 3. Density estimates (indiv.m^{-2}) of gastropod snail species at selected sites in Lake Edward, January 2008.

Among Dipteran larvae, *Chaoborus* sp. and *Tanypus* sp. were prominent at most of the sites with highest densities recorded at Kazinga inshore, Kishenyi and Rwenshama offshore (5966, 2689 2170 indiv. m^{-2} respectively for *Chaoborus* sp. and 2521, 1442, 350 respectively for *Tanypus* sp.). *Tanytarsus* sp. was recovered only at Kishenyi inshore with a density value of 1162 indiv. m^{-2} (Fig. 4). *Chironomous* sp was prominent at Kishenyi inshore (1008 indiv. m^{-2}) and Rwenshama offshore (938 indiv. m^{-2}).The remaining dipterans occurred with generally low densties (< 500 indiv. m^{-2}). *Nais* sp. (Oligochaeta), a common macro-benthos constituent at all sites occurred with relatively low densities 238-518 indiv. m^{-2}) (Fig. 5).

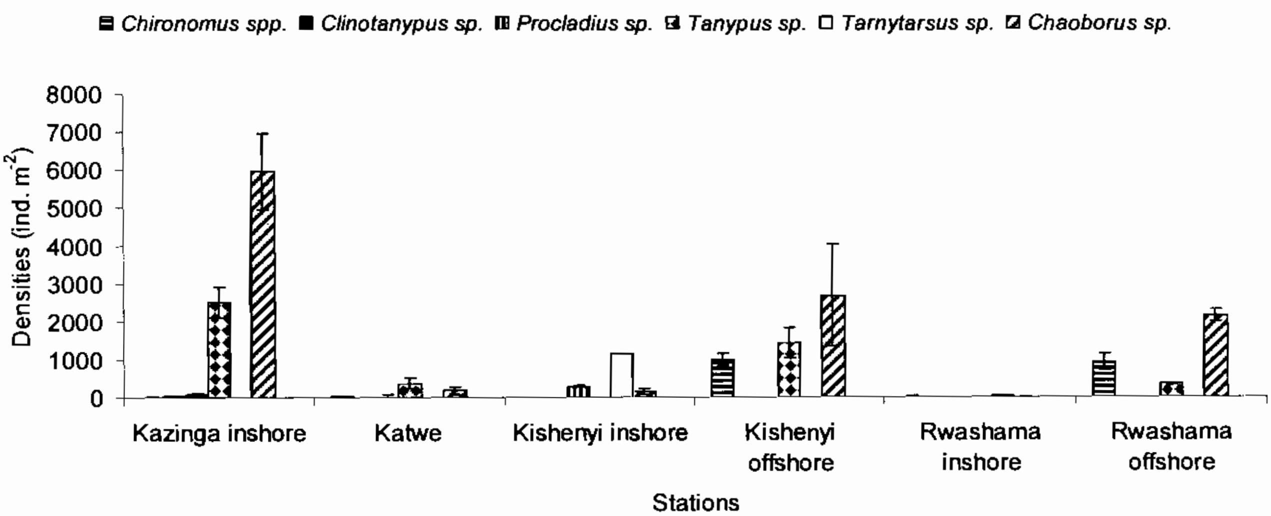

Figure 4. Density estimates (indiv.m^{-2}) of lakefly larvae at selected sites in Lake Edward, January 2008

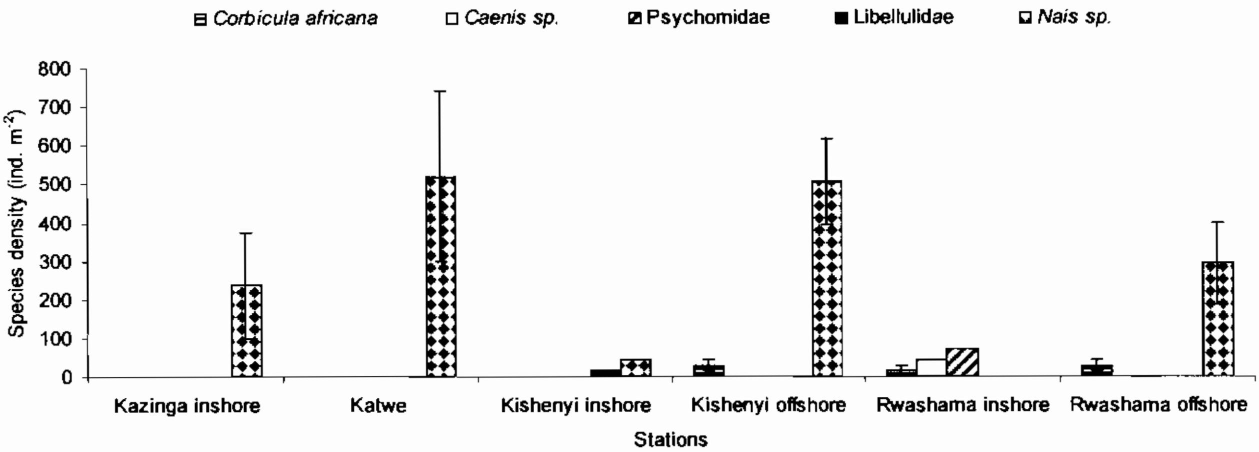

Figure 5. Density estimates (indiv.m^{-2}) of other macro-benthos taxa at selected sites in Lake Edward, January 2008

Combined abundance estimates for the broad groups of macro-benthic organisms showed that Dipteran/ lakefly larvae were the single most abundant group nearly at all sites (126-8641 indiv. m^{-2}) although considerable inter-site variation was apparent (Fig 6) .

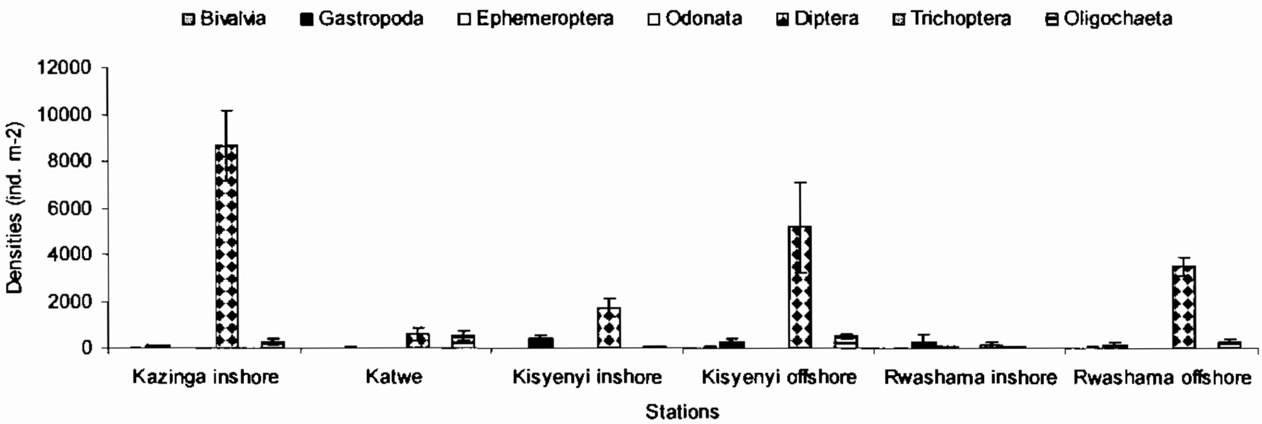

Figure 6. Combined abundance estimates of the broad taxonomic groups of macro-benthos at selected sites in Lake Edward, January 2008

Discussion

Micro-invertebrates (Zooplankton)

The zooplankton community in Lake Edward is dominated by Copepoda in particular, cyclopoid copepods in terms of distribution and abundance patterns as exhibited in the present study. Copepods were a widely distributed group occurring in much higher numerical abundance than any other zooplankton group in the survey area. Results of this study demonstrate that due ti their abundance copepods are the drivers of the notably high overall zooplankton abundance in this lake. Earlier, but recent density estimates showing over 1 million indiv m^{-2} at most field sites in the lake appears to corroborate the high density values of this survey. The zooplankton density estimates from this study (up to 4m indiv. m^{-2}; Fig. 2) are some of the highest recorded in Ugandan lakes. This has ecological implications with respect to the food web of the lake. Inn Lake Victoria, copepods have been recorded to occur in higher abundance relative to other zooplankton groups and this has been attributed to a good food environment (i.e. suitable algal crop and other organic particles). Where copepods have been found to occur in high abundance, this has been associated with development of a thriving pelagic fishery as these organisms provide the bulk of nutrition for key pelagic fish species such as mukene, *Rastrineobola argentea* (Mwebaza-Ndawula 1998), which now ranks number one in fish biomass. However, in Lake Edward, pararell fish studies have shown no presence mukene. The rich zooplankton crop of the lake appears to be trophically cropped by *Haplochromine* species of which *Yssichromis pappenheimi* is notable. The happlochromine stock in Lake Edward appears to be very rich (pers comm. Dismas Mbabazi), probably supported by the superabundant zooplankton food resource. It is however not established whether the pelagic fishery is currently under any commercial exploitation. The copepod community of the lake, by virtue of its ecological attributes (i.e. wide distribution and very high abundance levels: refer to Table 1 & Fig. 2) constitutes a suitable candidate as a monitoring indicator for seismic developments on the lake.

Although over-shadowed by the superabundant cyclopoid copepds, the Cladoceran community of this lake is unique in a number of aspects. These include wide spatial distribution and comparably higher numerical abundance than is usually encountered in Uganda. However in a previous study (Mwebaza-Ndawula et al. 2007) the cladoceran community was reported to be sparse as is the case in many other water bodies. Thus, the unusual relative prominence of the group in the present study may be due to seasonal oscillations influenced by various environmental factors such as predation.

Benthic macro-invertebrates

The benthic mollusk fauna in the shallower areas of Lake Edward has been reported to be very poor in number and density of species (Mandahl-Barth, 1954). The present survey shows the benthic community of the lake having some distinctive groups represented by the lakefly larvae and gastropod snails. These two groups are ecologically important on account of their recovery at all sites investigated and their occurrence in high numerical abundance (Figs 3 &4). The gastropod species, *Melanoides tuberculata* is singled out in this category while among the lakefly larvae, *Chaoborus* sp. and *Tanypus* are notable. Their ecological attributes have significant functional implications in the Lake Edward ecosystem. The observed high abundance of *Chaoborus* (up to 8000 indiv. m^{-2}) represents one of the highest abundance records of this group in Uganda. Macdonald (1956) reported 2000 indiv. m^{-2} at Ekunu bay in Lake Victoria and subsequent records by Mbahinzireki (993) and Okedi (1990) have not differed so much from this figure. These observations also suggest inadequate cropping of a rich food resource by both bottom feeding and pelagic fishes, and sets promise for their potential utilization in fishery production. These two macro-invertebrate groups (lake fly larvae and gastropods) merit candidacy as monitoring indicators for seismic developments on the lake.

In general, invertebrate communities are known to respond to changes in environmental conditions. The responses can be manifested in form of changes in community composition, species richness and abundance. This is because organisms exhibit varying levels of tolerance to environmental change; ranging from reduction of species numbers and abundance to total elimination of the least tolerant groups. When such severe community responses occur, this will imply consequences to the production dynamics especially when the normal food web functions are disrupted. Therefore as oil exploration and production activities unfold on the lake, it is important to understand the basic environmental principles involved and take appropriate options with emphasis to monitoring surveys so as to track any possible impacts that can cause wide-ranging ecosystem disturbances.

3.3 Aspects of fish biology and ecology

Species composition, abundance and distribution

A total of six non-haplochromine and 14 haplochromine fish species were recorded from the three habitats of the lake sampled Table 1). Kishenyi an open water habitat recorded all the 14 haplochromine species but only two non-haplochromines species (*Bagrus docmak* and *Protopterus aethiopicus*)

Table 1: Fish species recoded from gillnets from Lake Edward (Uganda) January 2008.

Spieces	**Kazinga**	**Kishenyi**	**Rwenshama**
Non-Haplochromines			
Bagrus docmak	√	√	√
Barbus altianalis			√
Clarias gariepinus	√		√
Oreochronis leucostictus	√		√
Oreochronis niloticus			√
Protopterus aethiopicus	√	√	
Haplochromines			
Astatotilapia aeneocolor	√	√	√
Astatotilapia elegans	√	√	√
Astatotilapia macropsoides	√	√	
Astatotilapia oregosoma	√	√	√
Enterochromis nigripinnis	√	√	√
Guarochromis angustifrons		√	√
Haplo elongate		√	
Haps (lipochromis like)		√	√
Harpagochromis mentatus		√	
Harpagochromis squamipinnis	√	√	√
Labrochromis mylodon	√	√	√
Psammochromis schubotzi	√	√	√
Schubotzi eduardiana		√	√
Yssichromis pappenheimi	√	√	√

Analysis of proportions by numbers indicate 95.9% of the fishes retained in experimental gillnets were haplochromines cichlids. The six non-haplochromine species encountered only accounted for 4.1% by numbers. The proportions of the haplochromine and non-haplochromine species by weight were 76.4 and 23.6% respectively. The dominant non-haplochromine species in the experimental catches was *Bagrus docmak* while the haplochromines were dominated by a small (7-8 cm Total lenth) endemic haplochromine species – *Entrochromis nigripinnis*. Rwenshama papyrus site recorded most of the significant proportions of non-haplochromine fishes especially the riverhine species *Barbus altianalis* (Table 2) due to presence of many rivers emptying into the adjoining wetland.

Table 2 : Proportions (by numbers and weight) of the various fish species recorded from three sites on Lake Edward (uganda)

	Kazinga		Kishenyi		Rwenshama	
Species	Marshy vegetation shore		Open water		Papyrus shoreline	
Non-Haplochromines	% Nos	% Wt	% Nos	% Wt	% Nos	% Wt
Bagrus docmak	0.5	3.2	0.4	5.8	2.0	13.4
Barbus altianalis					6.5	14.5
Clarias gariepinus	0.1	2.7			0.8	16.7
Oreochronis leucostictus	0.1	0.7			0.8	2.3
Oreochronis niloticus					0.9	3.8
Protopterus aethiopicus	0.2	4.9	0.1	2.6		
Haplochromines						
Astatotilapia aeneocolor	0.6	6.5	6.0	10.4	4.8	4.6
Astatotilapia elegans	0.3	0.2	50.9	33.4	17.9	8.5
Astatotilapia macropsoides	0.2	0.6	0.2	0.1		
Astatotilapia oregosoma	0.3	0.2	2.2	1.8	1.6	2.1
Enterochromis nigripinnis	88.7	58.8	21.7	9.0	38.2	8.9
Guarochromis angustifrons			0.2	0.4	0.2	0.2
Haplo elongate			1.1	0.3		
Haps (lipochromis like)			0.2	0.3	1.7	2.1
Harpagochromis mentatus			1.3	2.3		
Harpagochromis squamipinnis	3.0	9.8	2.0	4.4	5.4	8.7
Labrochromis mylodon	3.2	4.6	1.3	2.2	1.1	0.8
Psammochromis schubotzi	2.4	6.7	11.5	26.3	10.1	8.8
Schubotzi eduardiana			0.2	0.1	3.8	2.6
Yssichromis pappenheimi	0.3	0.8	0.9	0.7	4.1	2.1

Catch rates

Catch rates by numbers (number of fish caught/net/day) reduced with increase in mesh size (Fig 2) indicating an increase in small-bodied fishes and the young of large-sized fishes. The catch rates were highest (58 ± 24 fish/net/day) in 1" mesh size net and decreased rapidly to 17 ± 5 in 1.5" net. Nets larger than 3" recorded a mean catch rate of about 1 fish per net per day while nets of stretched mesh size ≥ 5" rarely retained a single fish. This suggests that smaller fishers < 20 cm Total length that can be effectively retained by nets of mesh sizes ≤ 2" make up the largest proportion in biomass of the lake. Catch rates by weight (Fig 2b) also showed a similar reducing trend although 3.5" and 4.5" mesh size nets recorded slightly higher catch rates but with wider error margins.

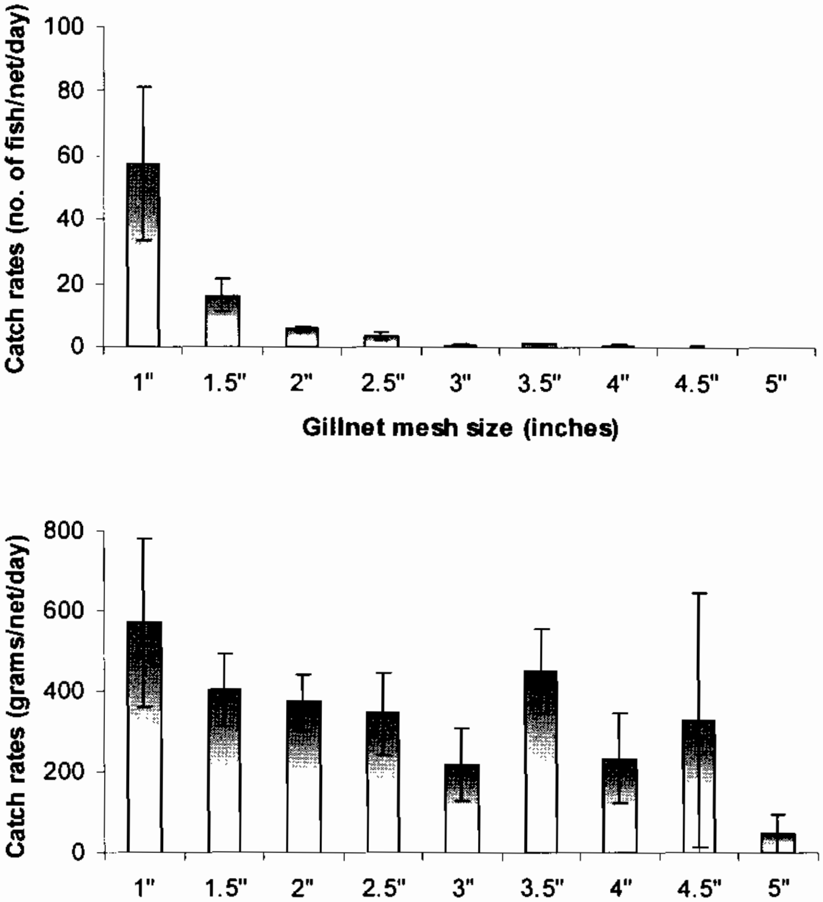

Fig 2. Catch rates of gillnets of various mesh sizes by a) numbers and b) weight from Lake Edward Uganda

Species diversity and richness

The Shannon diversity index was highest (2.03) at Rwenshama, a papyrus shoreline followed by the open water station of Kishenyi (1.53). The marshy vegetation habitat at Kazinga recorded the lowest diversity index (0.56) due to dominance by a smaller haplochromines - *Entrochromis nigripinnis* (88.7% by numbers) Table 2.

Analysis of fish diversity with distance from shore from the two sites (Kazinga and Rwenshama) where fleets were set along the shore varied between the two sites. Whereas diversity increased with distance from shore at Kazinga (marshy vegetation shoreline, the offshore fleet at Rwenshama recorded lower diversity index (1.57) compared the inshore and offshore (Fig 3). The low (0.2) diversity index of fishes recorded in the inshore fleet at Kazinga is due dominance of a single haplochromines species *Entrochromis nigrpinnis* that appears to be closely associated with marshy vegetation that characterise the shoreline.

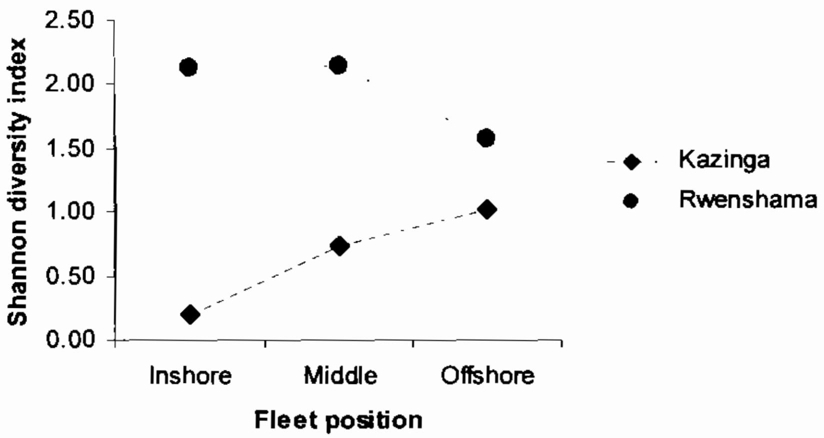

Figure 3: Fish diversity indices recorded from various fleet positions at two sampling stations on Lake Edward

Size structure

The size structure of the two important commercial fish species Nile Tilapia and *Bagrus dockmak* (Semutundu) retained in experimental gillnet surveys on lakes Edward show that the population is skewed to the juveniles. This is a common feature of fish populations even in other major aquatic systems Albert, Kyoga, and Victoria. The modal size of *Bagrus* was between 19 and 21 cm TL which is about one and a half year class cohort. The number Nile tilapia retained is experimental gillnets was too small to generate a realistic impression of the size structure. Opportunistic samples obtained from commercial fishery suggested a stable population comprising sizes smaller than the average Lake Victoria tilapiines.

Sex ratios

The sex ratio of *Bagrus docmak* (Semutundu) was 16 females for every 10 males~2:1. This suggests a stable population capable of replenishing its stocks. Although the numbers of the major commercial fish species retained in experimental gillnets and examined for gonad maturity and sex were small, the populations of Nile tilapia (Ngege), *Barbus altianalis* (Kisinja), *Clarias gariepinus* (Male), *Oreochromis leucosticus* (Ngege), were composed of more males than females (Table 3).

Table 3: Sex ratios, maturity and breeding conditions of the commercial fish species from Lake Edward

		Sex ratios			
Species	No of fish examined	Males	Females	% Mature	% breeding
Bagrus docmak	26	10	16	23.1	3.8
Barbus altianalis	23	10	3	43.5	17.4
Clarias gariepinus	8	10	3	12.5	0.0
Oreochromis leucostictus	9	10	3	66.7	22.2
Oreochromis niloticus	12	10	4	88.9	44.4
Protopterus aethiopicus	4	10	10	50.0	0.0

Breeding conditions

The proportions of the various commercial fish species that were sexually mature and those in breeding condition are given in Table 3 above. The proportions that were mature were more than 40% except for *Clarias* and *Bagrus.* The proportions of the mature fishes that were either in breeding condition or had enhanced gonads and reproductive cells in preparation for breeding were generally low (< 50%). This survey was conducted in January which is within the long dry spell in the Albertine rift region. Most fishes in Lake Victoria region are known to show peak breeding during the long and short rain seasons. Much of the fish fauna of lake Edward is similar to those of lake Victoria and Kivu and are believed to be from a common ancenstry. This could suggest that they show similar growth patterns and breeding periodicity.

Fishers indicated that their catches increase during rainy seasons and that by that time most of their fish have eggs. This is a direct correlation of scientific findings with indigenous knowledge from the local resource users.

Condition factor

The Fulton condition factor for the commercial fishes in Lake Edward (Nile tilapia – 2.2, *Barbus altianalis* – 1.5, *Clarias gariepinus* – 0.8, *Oreochromis luecosticus* – 1.9, *Bargrus docmak* – 1.2, and *Protopterus aethiopicus* – Lungfish (0.4) are comparable with values from Lake Victoria. The condition factor for the Nile tilapia at 2.2 suggests a stable population state. The fisheries of Lake Edward which is surrounded by Queen Elithabeth National park in Uganda and Virunga national park in Democratic Republic of Congo are controlled. A stable growth rate stable is a key indication of a fishery that is not stressed. It could therefore suggest that the fisheries of Lake Edward are still in a viable state probably due to the control measures.

Food and feeding

Stomachs of *Bagrus docmak* examined contained Odonata (47.6%) and fish (mainly haplochromines and unidentified fish remains35.2%). Other insect items ingested by Bagrus included chironomids (6.2%), Choabrids (2.0%) and Ephemeroptera (1.5%). With over 90% of the biomass in the lake comprising haplochromines (see section on species composition), *Bagrus* has plenty of food for its adult stages while the juveniles can effectively feed on insects that appear to be plentiful. The other predatory fishes in the lake *Clarias* and *Protopterus* fed mainly of insects and molluscs respectively.

Nile tilapia that is known to be omnivorous (Balirwa, 1998; Mbabazi, 2004) fed mainly on insect prawns (Cladocera and copepods) 12.1%, detritus 11.3% and a mixture of algae comprising 76.7%. The algal groups ingested by Nile tilapia were diatoms 25.6%, Blue greens (39.7%) and greens (11.3%).

3.4. Fish Catch Assessment

Fishing effort

The total number of fishing boats operating at the five landing sites was 302, of which 258 boats used gillnets, 40 boats used long line hooks and four used basket traps (Table 1). Katwe landing site had the highest number of fishing boats (85), followed by Rwenshama (71), Kishenyi (61), Kazinga (48), and Kayanja (37).

Table 1. The total numbers of active boats with different fishing gears operating at each landing site

Gear type	Katwe	Kayanja	Kazinga	Kishenyi	Rwenshama	Total
Gillnets (4 inch mesh)		1		3	20	24
Gillnets (4½ inch mesh)	80	26	45	44	35	230
Gillnet (5 inch mesh)		1		1	2	4
Long line hooks	5	9	3	12	11	40
Traps				1	3	4
Total	**85**	**37**	**48**	**61**	**71**	**302**

Species composition of the fish catches

Seven fish species/taxa were encountered in the fish catches at the landing sites sampled. These included: *Oreochromis niloticus, Bagrus docmak, Protopterus arthiopicus, Clarias gariepinus, Oreochromis leucostictus, Barbus altianalis*, and Haplochromines.

Fish catch rates

Boats using three types of fishing gears were encountered and sampled at the four landing sites but the occurrence of these gears varied between the landing sites and they were dominated by gillnets. At Katwe, Kazinga and Kishenyi only gill nets and long lines were encountered whereas catches of basket traps were sampled at Rwenshama in addition to the former two gears (Table 2).

Table 2. Numbers of boats sampled per gear type at four landing sites in Lake Edward.

Landing site name	Basket traps	Gillnets	Long line	Total
Katwe		43	5	48
Kazinga		28	1	29
Kishenyi		38	6	44
Rwenshama	2	42	4	48
Total	2	151	16	169

Katwe landing site

At Katwe landing site, *B. docmak* had the highest catch rates (4. 8 kg/boat/day) in the gillnet fishery whereas in long lining boats, *P. aethiopicus* showed the highest catch rates (9.5 kg/boat/day) (Table 3). After pooling data from all boats sampled, irrespective of fishing gear, *B. docmak* had the highest catch rate (4.5 kg/boat/day) followed by *P. aethiopicus* (2.5 kg/boat/day) and *O. niloticus* (1.2 kg/boat/day) whereas the contribution of other species was minor (i.e. ≤0.3 kg/boat/day).

Table 3. Fish catch rates (kg/boat/day) at Katwe landing site, January 2008.

Species	Basket traps	Gillnets	Long line	All boats pooled
Oreochromis niloticus		1.3	-	1.2
Haplochromines		0.1	-	0.1
Bagrus docmak		4.8	0.7	4.4
Protopterus aethiopicus		1.7	9.5	2.5
Clarias gariepinus		0.3	0.9	0.3
Oreochromis leucostictus		-	-	-
Barbus altianalis		0.01	-	0.01

Kazinga landing site

At Kazinga landing site, *O. niloticus* had the highest catch rates (8.2 kg/boat/day) in the gillnet fishery whereas in the long lining fishery, a single boat was sampled and it landed 81.5 kg (Table 4). After pooling data from all boats sampled, irrespective of fishing gear, *O. niloticus* had the highest catch rate (7.9 kg/boat/day) followed by *B. docmak* (4.97 kg/boat/day), *P. aethiopicus* (3.6 kg/boat/day) and *C. gariepinus* (0.7 kg/boat/day). The other species landed made insignificant contribution to the catches (I,e. ≤ 0.2 kg/boat/day)..

Table 4. Fish catch rates (kg/boat/day) at Kazinga landing site, January 2008

Species	Basket traps	Gillnets	Long line	All boats pooled
Oreochromis niloticus		8.2	-	7.9
Haplochromines		0.5	-	0.2
Bagrus docmak		4.6	15.5	5.0
Protopterus aethiopicus		0.8	81.5	3.6
Clarias gariepinus		0.4	7.0	0.7
Oreochromis leucostictus		0.01	-	0.01
Barbus altianalis		0.1	-	0.1

Kishenyi landing site

At Kishenyi landing site, like at Kazinga, *O. niloticus* had the highest catch rates (11.5 kg/boat/day) in the gillnet fishery whereas in the long lining fishery, *P. aethiopicus* had the had the highest catch rate of 14.3 kg/boat/day (Table 5). After pooling data from all boats sampled, irrespective of fishing gear, *O. niloticus* had the highest catch rate (9.9 kg/boat/day) followed by *B. docmak* (4.7 kg/boat/day), *P. aethiopicus* (2.9 kg/boat/day) and

C. *gariepinus* (0.7 kg/boat/day). The other species landed made insignificant contribution to the catches (i.e. ≤ 0.1 kg/boat/day).

Table 5. Fish catch rates (kg/boat/day) at Kishenyi landing site, January 2008

Species	Basket traps	Gillnets	Long line	All boats pooled
Oreochromis niloticus		11.5	-	9.9
Haplochromines		0.1	-	0.1
Bagrus docmak		4.5	5.9	4.7
Protopterus aethiopicus		1.1	14.3	2.9
Clarias gariepinus		0.3	3.5	0.7
Oreochromis leucostictus		0.0	-	0.0
Barbus altianalis		0.1	-	0.1

Rwenshama landing site

At Rwenshama landing site, *P. aethiopicus* had the highest catch rates in the fishery with basket traps (12.9 kg/boat/day) whereas in the gillnet fishery, *O. niloticus* had the highest catch rate of 14.0 kg/boat/day and *P.aethiopicus* had the highest catch rate in the long line fishery (16.1 kg/boat/day) (Table 6). With the data pooled for all sampled boats irrespective of fishing gear, *O. niloticus* had the highest catch rate (12.4 kg/boat/day) followed by *B. docmak* (6.9 kg/boat/day), *P. aethiopicus* (2.5 kg/boat/day) and *C. gariepinus* (0.9 kg/boat/day). The other species landed contributed ≤ 0.2 kg/boat/day.

Table 6. Fish catch rates (kg/boat/day) at Rwenshama landing site, January 2008.

Species	Basket traps	Gillnets	Long line	All boats pooled
Oreochromis niloticus	4.8	14.0	-	12.4
Haplochromines	-	0.2	-	0.2
Bagrus docmak	1.0	7.2	6.8	6.9
Protopterus aethiopicus	12.9	0.8	16.1	2.5
Clarias gariepinus	9.0	0.2	4.3	0.9
Oreochromis leucostictus	0.7	-	-	0.03
Barbus altianalis	2.0	0.1	-	0.2

Trend of fish catch rates across the landing site

The catch rates of the four major fish species in the catch, i.e. *O. niloticus, B. docmak, P. aethiopicus* and *C. gariepinus,* generally increased southwards with the extreme low at Katwe and highest at Rwenshama (Figure 1). The catch rates at Kazinga and Kishenyi were similar and moderate compared with the two extremes. The largest disparity in catch rates between landing sites was observed in the tilapia fishery. The overall the catch rates for all species together increased from 8.4 kg/boat/day at Katwe, to 17.4 kg/boat/day at Kazinga, 18.3 kg/boat/day at Kishenyi and 23.1 kg/boat/day at Rwenshama.

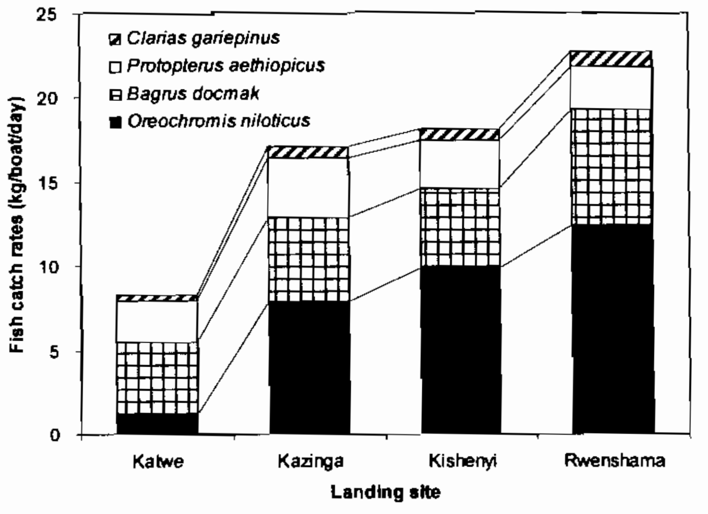

Figure 1. The trend of catch rates of the four major species across the sampled landing sites, January 2008.

Estimates of the total fish catches

The total fish catches at the four sampled landing sites for the month of January 2008 were estimated at 108 t (Table 7). Out of this, in the order of importance, *O. niloticus* contributed 43.7 t (40%), B. docmak 34.8 t (32%), *P. aethiopicus* 23.3 t (22%), and *C. gariepinus* 4.9 t (4%). All other fish taxa contributed approximately 2% of the estimated total catches. The total fish catch estimates were highest 39.2 t at Rwenshama, followed by Kazinga 25.4 t, Kishenyi 24.1 t, and least at Katwe (19.0 t). These estimates should however be taken as indicative figures of importance of the different fisheries and are only meant for future comparisons. This is because they are based on a sample of one day at each landing site without taking into consideration various environmental conditions including season, weather and the phase of the moon.

Table 7. Estimated Total fish catches (tonnes) at four landing sites on Lake Edward for January 2008

Species	Katwe	Kazinga	Kishenyi	Rwenshama	Total
Oreochromis niloticus	2.8	10.0	11.8	19.1	43.7
Haplochromines	0.2	0.2	0.1	0.2	0.8
Bagrus docmak	10.4	6.8	6.1	11.4	34.8
Protopterus aethiopicus	4.8	7.5	4.8	6.1	23.3
Clarias gariepinus	0.7	1.1	1.2	1.9	4.8
Oreochromis leucostictus	-	0.0	0.0	0.0	0.1
Barbus altianalis	0.0	0.1	0.1	0.3	0.5
Total	19.0	25.7	24.1	39.2	108.0

Estimates of the gross beach value of the catches

The gross value of the fish catches at the four landing sites for the month of January 2008 was estimated at shs 91.9 million contributed by *O. niloticus* 54%, *B. docmak* 36%, *P. aethiopicus* 9% and *C. gariepinus* 1% (Table 8). Rwenshama landing site had the highest share of the beach value of shs 31 million (34%), followed Kazinga landing site (shs 24 million (26%)). Kishenyi and Katwe landing had similar gross revenue, each constituting approximately shs 18 million (20%) of the gross beach value.

Table 8. The estimated gross beach value of catches (Shs) at four landing sites on Lake Edward for January 2008

Species	Katwe	Kazinga	Kishenyi	Rwenshama	Total
Oreochromis niloticus	3,296,522	15,882,459	12,035,993	18,305,228	49,520,202
Haplochromines	19,088	11,985	4,872	3,059	39,005
Bagrus docmak	12,086,394	6,199,383	4,498,597	10,348,360	33,132,735
Protopterus aethiopicus	2,723,331	1,688,269	1,824,115	2,022,504	8,258,219
Clarias gariepinus	143,055	178,599	302,377	320,596	944,627
Oreochromis leucostictus	-	224	92	958	1,274
Barbus altianalis	916	19,340	11,239	14,058	45,552
Total	18,269,306	23,980,259	18,677,285	31,014,763	91,941,614

Size of the fish catches

The analysis of the mean weight of the four main commercial fish species shows that the mean weights of *O. niloticus* and *Bagrus docmak*, which are common in the catches of gillnets were lowest at Rwenshama (Table 9). The modal total length of *O. niloticus* was 25 cm at Rwenshama compared with 28 and 29 cm at Kazinga and Kishenyi respectively (Figure 2). The length frequency *Bagrus docmak* also showed less spread to larger sizes at Rwenshama than at other sites (Figure 3). This corresponded with the highest occurrence of 4-inch mesh size gillnets which were common at Rwenshama compared with other landing sites where gillnets were predominantly 4½ inch mesh size. The largest mean size of both *P. aethiopicus, C. gariepinus* was at Kazinga landing site and the smallest at Kishenyi landing site.

Table 9. The mean weight (kg) of the major fish species in the catch excluding

Species	Katwe	Kazinga	Kishenyi	Rwenshama
Oreochromis niloticus	0.45	0.45	0.50	0.35
Bagrus docmak	0.87	0.81	0.73	0.63
Protopterus aethiopicus	2.57	2.94	1.78	2.30
Clarias gariepinus	1.68	1.88	1.62	1.66

3.5. Socioeconomics

Livelihood dependence on fish and fishery activities for food and income were key issues to the majority (>70%) of responses who also emphasized the need for enforcement of fisheries laws. However, fishers were generally aware of the existence of oil-related activities and the likely presence of oil reserves based on past occasional sightings of oily substances on the lake with the expressed concern that oil exploitations was not likely to benefit the fishers and others in the fishing business as they would be forced to move away from the fish landings and from the lake resulting into loss of livelihood.

3.5.1. Full time jobs supported by the fishery

There were a total of 1297 fishers, 38 net repairs, 16 boat builders, 5 BMU chairpersons and 5 beach guards all men on the entire four landing sites. Food and tea/coffee/porridge was being prepared by a total of 59 people, 93 % women comprising the entire labor force. There were 262 fish traders 28% comprising women and 33 fish processors 30 % women. The details of the other fishery related activities supported by at the five landing sites on Lake Edward, Uganda are indicated in Table 2. The other economic activities being carried out in the area included cattle rearing and tourism.

Table 3.1 The different activities supported by the fishery on the five landing sites on Lake Edward, Uganda during December 2006 (M= male; F= female).

Sub county	**Bwambala**		**Katunguru**				**Katwe-Kabatooro**					
Landing site	**Rwenshama**		**Kishenyi**		**Kazinga**		**Katwe**		**Kayanja**		**Overall**	
Parameter	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
Boat builders	-	-	1	-	1	-	10		1	-	16	-
Food vendors	3	-	1	-	-	8	-	30		-	4	55
Net repair(s)	3	-	2	-	10	-	20		3	-	38	-
Cleaner fish landing	1	-	1	-	-	-	-	6	1	-	3	6
Fisher(s)	311	-	220	-	160	-	480		126	-	1297	-
Fish trader(s)	50	15	19	11	8	7	50	30	61	11	188	74
Fish processor(s)	13	9	3	1	1		1	1	2	2	20	13
Fish cleaner	-	-	6	-	-	-	4	4		-	10	4
Chairperson landing	1	-	1	-	1	-	1		1	-	5	-
BMU Committee member(s)	7	3	9	-	9	-	9	4	9	-	43	7
Fisheries staff	1	-		-		-	1	1		-	2	1
Askali of landing	1	-	1	-	1	-	1		1	-	5	-
Boat owners	71	-	59	-	54	-	100	38	43	5	327	43

Among the key Informants the main concern and related issues captured from content analysis were:

1. During seismic surveys, fishing vessels may have to avoid the areas where the surveys are being done or vice versa.

2. A potential exists for short-term inconvenience and disruption to patterns of fishing during surveys.
3. Short-term reduction in catch rates is expected because shooting is likely to disrupt, food availability for and for fish to migrate from the survey area.
4. The need to sensitize all stakeholders on the real negative impacts of seismic activities that are associated with explosions and vibrations that could lead to a disappearance of fish.
4. Implementation of mitigation measures for the affected communities based on results of the EIA
5. Provision of information to stakeholders regarding each step undertaken during the seismic activity and how it could impact fish stocks, fishing and alleviation of impacts associated with the activity
6. Ensuring access to fishing and equal alternatives livelihood for the affected communities.

4.0 CONLUSIONS AND RECOMMENDATIONS

4.1 WATER QUALITY

4.1.1 Conclusions

1. Conductivity and pH of the waters of Lake Edward have remained stable over the years
2. Given that the TN:TP ratios were less than the conventional Redfield ratio of 16:1, it may imply N-deficiency but verification needs to done through N-debt experiments
3. Concentration of SRSi did not explain variability in biomass of diatoms

4.1.2 Recommendations

What is likely with seismic activity and how to mitigate?

1. Depending on the timing, magnitude and frequency of seismic activity, it is recommended that the level of impact be contained so as not to result in re-suspension of bottom deposits that would reduce water clarity.
2. The Kazinga Channel is in comparison to Lake Edward more dilute)based on conductivity/total ionic content); it therefore recommended that seismic activity be of such magnitude as to not to cause back-flow into Kazinga Channel with potential consequences on water quality and ecology
3. Detailed studies are required to document the relationship between the various limnological parameters and fish production so as to cover a full seasonal cycle to guide seismic activity

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4.2 INVERTEBRATE FAUNA

4.2.1 Conclusions

1. The aquatic micro-invertebrate (Zooplankton) community was dominated by cyclopoid copepods (largely *Thermocyclops neglectus*).
2. The aquatic macro-invertebrate community was dominated by the lake fly largely *Chaoborus* larvae.
3. *Thermocyclops neglectus* and *Chaoborus* larvae appear to be widely distributed in the lake and occur in high numerical abundance with positive ecological implications especially trophic sustenance of the pelagic fish communities.
4. By virtue of these attributes the above mentioned two categories of invertebrates are considered to be suitable as environment monitoring indicators for the proposed seismic activities on the lake.
5. Most invertebrates have pelagic or planktonic life cycle and like fish larvae or eggs are susceptible to mortality within 1 metre distance from the seismic source.

4.2.2 Recommendations

1. The current data collected during the dry season needs to be supplemented by further regular data collections in order to bring out seasonal aspects of the invertebrate community in the lake.
2. The anticipated seismic activities need to consider minimizing of widespread ecological disturbances of the Lake Edward ecosystem such as strong blasts that are likely to disrupt the lake's sediments which are critical habitats for a number of aquatic animals i.e. macro-benthos, diurnally migrating zooplankton and demersal fishes.
3. Due to their small size zooplankton may behave like fish eggs and fish larvae and could therefore be prone to similar mortalities associated with seismic impacts on fish.

4.3 ASPECTS OF FISH BIOLOGY AND ECOLOGY

4.3.1 Conclusions

1. Results from this survey show that 96% by numbers and 76% weight of all the fishes in Lake Edward are haplochromines. The offshore station recorded more haplochromine biomass than the near shore stations suggesting higher biomass of pelagic haplochromines in open waters.
2. Inshore fish species diversity was highest at Rwenshama a wetland site. Management measures should be directed to protect the shallow inshore areas of that are associated with high diversities of fish, vital feeding, breeding and nursery grounds.
3. The fish populations revealed presence of large quantities of juveniles which could rise with advent of peak breeding season. The seismic surveys may also cause direct physical damage to adult fish within I metre distance from an air gun. However noise intensity that would result in mortality or other pathological effects has not been quantified.
4. Seismic activities may also cause short-term hearing damage to fish depending on fish species, distance from the air gun and sound wave characteristics.
5. Seismic shots are likely to elicit startle response in fish, resulting in a movement away from the source of the noise and changes in schooling behaviour.
6. This survey was conducted to generate baseline information on the status of the fisheries resources of the lake to guide future monitoring of developmental activities during oil exploration and production. These baseline facts are essential for decision making with respect to oil exploration and development in Lake Edward.

4.3.2 Recommendations

1. The loudness of the airgun bursts, frequency and duration of the proposed seismic activities should be tuned to ensure minimum interference to the inshore vegetated habitats to protect the vital feeding and breeding/nursery grounds and biodiversity.
2. The proposed seismic activities should ensure no disruption to the currently un-an exploited pelagic haplochromine fishery which is targeted for offsetting the increasing demand for both human and animal feed industry.
3. "Ramp-up" or "soft start" procedures a process whereby sound is gradually increased, not begun at full volume to give fish time to take evasive action should be adopted.
4. Establishment of survey-free spawning corridors and migration routes, which could not be done in this single survey.
5. Establishment of appropriate timing of migration or spawning for the keystone species which could not be established in a single survey.
6. It is likely that while adult fishes may avoid the direct effects of seismic survey (e.g. by moving away), the young and eggs of these fishes especially of mouth brooders could be destroyed, hence need to protect such habitats.
7. More systematic studies are required to consolidate information on the spatial and temporal characteristics of fish species richness, their biology: and ecology and to provide baseline on lake Edward upon which future monitoring of the various developments during oil exploration and production will be based to ensure the sustainability of the fisheries.

4.4 FISH CATCH ASSESSMENT

4.4.1 Conclusions

1. The commercial fisheries of Lake Edward depend on four main species, i.e. *O. niloticus*, *B. docmak*, *P. aethiopicus* and *C. gariepinus*, following that order of importance. The contribution of other fish taxa recorded in the catches, i.e. haplochromines, *O. leucostictus* and *B. altianalis* was in insignificant quantities.
2. Two main types of fishing gears, gillnets and long line hooks are used to catch the fish.
3. Out of the four sampled landing sites (Katwe, Kazinga, Kishenyi and Rwenshama) fisheries production was lowest at Katwe landing site, which happened to have the highest number of fishing boats. Local over fishing is likely to be responsible for the low catches at Katwe but other factors like seasonal fish migrations could have been at play.
4. With the exception of Katwe landing site, *O. niloticus* recorded the highest catch rates in boats using gillnets followed by *B. docmak* indicating that the two fishes were the main target of the gillnet fishery.
5. The boats using long line hooks recorded the highest catch rates of *P. aethiopicus* followed by *B. docmak* suggesting that the two species were the main targets of the hook fishery.

6. The high productivity of the tilapia in the Rwenshama area can be associated with the occurrence of natural supportive environments, especially wetlands, which provide nursery areas for young fish. This landing site also probably has a wider fishing range over which effort is expended, compared with the other sampled landing sites. However, there is also the factor of lowering the gillnet mesh size to 4 inch from the recommended 4½ inch in 35% of the boats using gillnets at Rwenshama. Because of this, the modal length of *O. niloticus* was actually lower than at other landing sites. The smaller gillnet mesh sizes select smaller sizes of fish and can make higher catches in the short term but can damage the fishery in the long term through recruitment over fishing.
7. The total catches from the four sampled landing sites were estimated at 108 t worth approximately shs 92 million at the boat level. The analysis of the gross beach value of the catches indicated that the fishers at Kazinga were obtaining the highest returns followed by Rwenshama and Kishenyi. The least income per fishing unit was at Katwe landing site.

4.4.2 Recommendations

1. The use of undersized gillnets of 4 inch instead of the recommended 4½ at Rwenshama landing site, which is probably contributing to the observed high catch rates of *O. niloticus* in addition to contributing to recruitment over fishing could lead to unrealistic evaluation of the effects of the seismic activities if changes in gear composition continues. The authorities at landing sites should be sensitized to ensure use the recommended gears and gear sizes.
2. The most important fishery in the lake is of a mouth brooder, *O. niloticus*. Seismic activity near shore areas if carried out during peak breeding, often associated with rainy seasons (March – May and October – November) would probably affect the subsequent recruitment and productivity. The timing of the seismic activities in these areas should therefore avoid such periods.
3. The baseline data were collected in a dry season and the situation of catches is likely to change with season, there is need to collect data in other seasons to obtain a representative and complete baseline dataset. This will enable distinguishing between the effects of fishing and the seismic activities.

4.5 SOCIOECONOMICS

4.5.1 Conclusions

1. During seismic surveys, fishing vessels may have to avoid the areas where the surveys are being done or vice versa.
2. A potential exists for short-term inconvenience and disruption to patterns of fishing during surveys.
3. Short-term reduction in catch rates is expected because shooting is likely to disrupt, food availability for and for fish to migrate from the survey area.
4. Short-term reduction in catch rates due to reduction in fishing time.

5. Ensuring access to fishing and equal alternatives livelihood for the affected communities.

4.5.2 *Recommendations*

1. The need to sensitize all stakeholders on the real negative impacts of seismic activities that are associated with explosions and vibrations that could lead to a disappearance of fish.
2. Implementation of mitigation measures for the affected communities based on results of the EIA
3. Provision of information to stakeholders regarding each step undertaken during the seismic activity and how it could impact fish stocks, fishing and alleviation of impacts associated with the activity.
4. Synchronize the timing of seismic surveys with those of fishing activities so that both can operate together in harmony.
5. Pre-planning can help minimize or eliminate the impact of reduced fishing time.
6. Compensation programs for gear damage and other fisheries impacts should be put in place.
7. Design surveys or adjust timing to avoid active fishing areas, especially fixed gear.

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APPENDICES

Appendix 1

National Fisheries Resources Research Institute (NaFIRRI)
Baseline survey with respect to seismic studies on Lake Edward

1.0. Introduction and Background to the study:

Lake Edward is the smallest of the great lakes of Africa. It is located in the western Great Rift Valley, on the border between the Democratic Republic of the Congo and Uganda, with its northern shore a few kilometers south of the Equator. Lake Edward lies at an elevation of 920 metres, is 77 km long by 40 km wide at its maximum points, and covers a total surface area of 2,325 km^2. The lake is fed by the Nyamugasani, the Ishasha, the Rutshuru, and the Rwindi rivers. It empties to the north via the Semliki River into Lake Albert.

Of recent, there has developed a strong devotion on the part of Uganda towards discovering and refining its own oil and lake Edward being one of the Lakes suspected to having oil, a seismic survey has been proposed to assess the possibility of the availability of oil. This is therefore one of the preliminary surveys in effect, aimed at capturing the social economics issues related to the fishers and the fishing business in regard to the seismic survey.

1.1. Objectives of the survey

d) Assessing the impact of the proposed seismic survey on the social economic issues related to the fishing business in and around Lake Edward.
e) Holding meetings with relavant fisheries stakeholders on issues related to those in 1 above
f) Draw from the findings appropriate measuers that would minimize the seismic negative impacts and enhance the positive ones.

1.2. Expected Output

1. Impact of the proposed seismic survey on the social economic issues related to fishing assessed.
2. Appropriate measures aimed at minimizing the sesmic negative effects on fishers and the fishing activities suggested.

2.0. Methodology

The survey was carried out on four landing sites of Rweshama in Rukungiri district, Kishenyi and Kazinga in Bushenyi district and Katwe in Kasese district.

Focus Group Discussions were held with fishers who mainly included boat owners; crew and fish traders and other people engaged in fisheries related activities. Discussions were also held with individual Fisheries Officers, Local Council Officials, BMU executives and some individual fishers information from which was quoted verbatim.

Data analysis was by use of content analysis. Statements from some key officials were noted verbatim

3.0. Findings from the survey:

3.1. Kishenyi landing site FGD: Fishers' Knowledge, prospected impact and possible remedies to the likely negative impacts of the seismic

NEMA people had just alerted some of respondents of the possibility of availability of oil and a possibility of carrying out research activities to confirm its availability.

According to the respondents Fish want peace so the activities associated with research aimed at confirming the availability of oil may make fish to migrate to other areas. They sited an example of when there is an earth quake which makes fish to scatter thereby leading to a reduction in fish catches what about the seismic whose vibrations and sound waves might be higher than those of earth quakes,? Fish will likely migrate to Congo moreover the Congolese could not allow the Ugandans to fish in their part of Lake Edward. Fish might also die as result of the seismic activities. As a result even fishing business as a source of food for communities on and around the lake, revenue for fishers, traders and districts will be negatively affected. Due to these prospected effects, members decided that alternative methods of confirming the availability of oil should be sought in order not to interfere with the fish in the lake.

However, if there are no alternative methods that cannot interfere with the fish in the lake, government should assess fishers incomes and see how to facilitate them (fishers) basing on their incomes from fishing. This can go on for the time the seismic survey is carried out, till the lake fishery is rejuvenated. The rejuvenation can be assessed through use of research. School fees for the fishers' children can also be paid by the seismic concerned authorities as fish from which they earn incomes will have reduced. Even when oil is discovered, people at local landing sites should be employed and half of the oil resources should be for the locals as even oil refining may cause adverse effects to the fish and local fishermen.

3.2. Kazinga landing FGD: Fishers' Knowledge, prospected impact and possible remedies to the likely negative impacts of the seismic

They had heard of the possibility of oil availability on the lake. Most of the fishermen said that they had been born at the landing and therefore such exercises like seismic should not displace them or make them loose their source of livelihood-fishing and other fishery related activities. A few especially those who had land/homes outside the landing site said that they could be compensated for the time they would spend without fishing if the exercise would affect their fishery production. People can also be given food and/or money to help them continue living if the fish are to decline. The others though advocated for being relocated if it so needed preferred to be relocated to another place on the lake where they can continue fishing. Most fishers reported that the seismic activities would kill the fish or would make fish to migrate to other places something that would drastically reduce their catches and incomes.

Fishers went ahead to express the fact that they were staying in a national park (Queen Elizabeth) where no cultivation is allowed to be carried out. Those who advocated continuing staying at Kazinga said that if fish catches were to decline some part of this park should be degazetted to enable them continue living. The other alternative was that of local projects like NAADs was carrying out poultry to enable them switch to new projects as an alternative source of income. The problem with NAADs was that it had facilitated only 2 people at this landing site but had trained almost every body at landing to engage in different activities especially poultry.

On the part of fishing, since the fish will decline, government should put security at the lake to ensure that Congolese do not fish on the Ugandan part of Lake Edward since even fish will have migrated to the Congolese part. Government can also buy for them engines such that they can go to offshore for fishing. Also after seismic, restocking can be considered to rejuvenate the lake.

3.3. Katwe Landing site FGD: Fishers' Knowledge, prospected impact and possible remedies to the likely negative impacts of the seismic

Some fishers had heard about it and were suspicious that they will be chased away during these processes. According to some fishers' observations, oil might be there because sometimes they saw oil like substances floating on the lake waters.

The seismic activities will kill the fish according to all members of the Focus Group Discussion. All members of the FGD did not support the whole oil venture including the seismic because they thought that it was going to deprive so many people engaged in fisheries related activities of their employment and source of income moreover the oil refining would not benefit all these people. Instead of venturing into oil refining, they argued government to reconsider restocking the lake because research findings according to them showed that fish stocks had declined. This should be accompanied by increasing enforcement to ensure adherence to fisheries rules as failure to adherence to fisheries rules was a major cause of the declining catches.

Local fishers say that tycooning kills the fish and said that seismic activity will kill the fish too.

"The main recommendation was that seismic means friendly to the fishing acitivities should be adopted such that people can continue fishing. Even when it comes to drilling oil, friendly means should be adopted. We need the oil and the fish at the same time. Recently there has been a shortage of oil in the country due to the chaos in Kenya and made Uganda to be in a crisis because the country did not have its own oil. So we need both oil and fish" Said Tumusime David a student who stays at Katwe landing site.

3.4. Rweshama FGD: Fishers' Knowledge, prospected impact and possible remedies to the likely negative impacts of the seismic survey

The respondents in the FGD had heard about the possibility of the availability of oil in and around lake Edward.

People here depend on fish and therefore they are worried that their fish will die or migrate to other places where effects of the seismic will not be felt. Mouth brooders will spit their eggs, which will affect the fish stocks and catches negatively. The respondents in the discourse said that they could not stop government from pursuing its activities. However, due to the fact that fish stocks and catches will decline and it's their only source of income being in an area which is gazetted as a national park they asked government to:

- Buy land for those without land outside the park where they can do cultivation.
- If fish decline to extremely low levels of catches, it means that their boats, gears and other fishing equipments will be rendered useless and government should assess their cost and compensate them.
- During the seismic, government should give locals money after a wide range of consultations and assessments of their on their incomes from fishing. Those who stay at the landing permanently only owning land there should be given more money compared with those who have homes and land outside landing site.
- There are many categories of people at landing sites so these should all be considered if the seismic activities affect the fish catches. These include among others the hoteliers who cook for the fishers who indirectly depend on the fisheries, net spreaders among others.

4.0. <u>Results of discussions with Local Fisheries Officers</u>

4.1. DFO, Kasese- Katswera Joseph

An EIA should be carried out to establish the possible side effects of the seismic on fish, people etc and devise measures to mitigate them. But more important to note is that the results of the EIA should be properly implemented. During tycooning, tilapia which is a mouth brooder spits its eggs, what about the seismic explosives?

The region whose people will have more negative effects during the seismic should be considered than others if there is to be any attempts to compensate the fishers and other people at beaches. Facilitation can be made available at community, sub county and district levels through initiatives otherwise every stakeholder should be put on board.

I have a feeling that seismic and oil refining will not be done on the whole lake and they will continue fishing in areas where such effects will not be experienced.

4.2. Masereka Amigo-Fishereis Officer, Katwe, Kasese

The fish can die due to high explosions and vibrations related to the seismic activities. If fish can die due to tycooning explosions, why not explosions and vibrations associated with the seismic activities?

4.3. Waswa Ronald-Ideological Assistant, Lake Edward, Katwe

The high explosions and vibrations shock and kill the eggs of fish so they will not allow such activities to take place on a source of livelihood for the many people.
The side effects of the Seismic activities towards the people and the fish should be taken into consideration and measures devised to ensure that people sustainable live better lives even after the seismic.

5.0. Results of Discussions with Local Council Officials

5.1. Zimbe Joseph- Local Council General Secretary/Data collector BMU Rweshama

I have heard of the possibility of availability of oil on this landing.

Seismic survey explosions, vibrations and location in the lake can have an effect on fish-can make fish to migrate to other areas and it may take long before they can come back to the areas where seismic will be carried out. As a result, government should give fishers money such that they can resort to other businesses during and after the seismic. This will help to create another source of livelihood other than entirely depending on fishery of Lake Edward.

5.2. Kiniga Sula-Chairman LC 11-Rwenshama

A team of people came here and erected red small flags and they said that wherever they were putting them were areas suspected to be having oil. I can't remember the year when they came here.

People will not have problems with the seismic as long as they are informed of whatever will happen during the process and continue fishing. Otherwise I do not know the effect that it will have on fish and the fishers.

5.3. Chairman LC 111, Katunguru Sub County, Bushenyi

In 1999 some people told me that there was a possibility of having oil deposits in and around this lake. During the seismic survey, fish can be disorganized-can migrate to other places where such activities will not be taking place. If the expolosions are dangerous to fishers health, the fishers can be facilitated and transferred during the activities and then brought back after the exercise. They can be brought back after a reasonable period of time when the Lake fishery production has been rejuvenated.

6.0. Results of the discussions with BMU executive members

6.1. Vice Chairman BMU, Kazinga

I had romours that we would be relocated to another place called Ruyinja during Seismic and oil exploration times, which we were not happy with. Generally we do not want to be relocated to another place or if they we are shifted it should be to another place where we can continue with our fishing activities.

During the Seismic activity, some fish will die or/and migrate to other areas where the effect of seismic activities will not be experienced which will directly reduce the fish catches and have a negative impact on their livelihoods. We call upon government to be on standby such that people can be facilitated in order not to negatively affect our standard of living. As a copying mechanism, other people can be employed in the activities because fish catches will reduce. However, People might be transferred as long as they are facilitated but prefer that if they are to be transferred, they should it should still able a place on Edward where they can continue fishing.

The high sounds might be dangerous to peoples health e g women are likely to experience discourages/still births etc and therefore such people can be facilitated to stay far away from such places during the seismic. The security that will be given for the seismicers should not disrupt fishers activities if fish will still be available in the lake.

6.2. Chairman BMU, Kazinga

People have been born here and want to continue staying here and therefore efforts should be made to ensure that they are helped if fish is to reduce by for example food, small money.

People at the beach should be sensitized about whatever will happen during the seismic such that they are aware and do not get scared in case such effects arise.

6.3. Chairman BMU, Katwe beach-Sulaiti Kasunzu

I am a lake dependant, born here, where do you transfer me if fish catches decline? Oil refining, will benefit one or a few persons unlike the fish which benefits many such that if a seismic is carried out on the lake and leads to migration and death of fish, so many people currently depending on the lake fishery will suffer due to lack of alternative sources of livelihoods.

I do not support these activities on Lake Edward because the high explosions can even lead to miscourages, stillbirths and deformations on the side of women and children

6. 4. Kishenyi Landing site-Mayanja John Patrick, Chairman BMU.

Research group came in 2007 and put flags and around areas they suspected to be having oil.

There could not be any problem except that the fish will scatter away and others die. The mature ones will leave their young ones which might result into their death. This can reduce the fish catches and peoples incomes. Due to this, government can give fishers money and they shift to other places until the lake fishery production is rejuvenated. He said that the number of people at landing site is between 1500 to 2000.

Even when it is threatening to rain or it rains, thunderstorms make fish to hide leading fishermen to come with very less or no fish at all, what about the seismic related activities?

6.5. Joseph Tibirinyebwa-Data collector Rwenshama

I heard information from some people from Kampala that there is a possibility of having oil in and around Lake Edward

6.6. Rubahamya Callist-Vice Chairman BMU, Rwenshama

I heard of the possibility of oil 4 to 5 years ago. Two African ladies came here in the first week of January 2008 and told me that a team of researchers would come to carry out research aimed at confirming oil availability.

Explosions and vibrations may affect our catches by resulting into a decline in catches. Fish can migrate to other areas where there are not such explosions and vibrations. Wherever there are explosions and vibrations in the waters fish runs away. Some fish can die in the course of scattering or the eggs and young fish can die if left behind by their mothers. This means that even incomes of fishers will decline.

Therefore those who are going to carry out the seismic activity should find away of supplementing the incomes of fishers as away of compensation for the effects of their seismic activities. They can do that by paying people a monthly income.
If the machines for the seismic activities are put in the waters for the exercise, the young fish will die. The mouth brooders like tilapia will spit their eggs out which will be a big loss. So they should not carry out seismic activity in the waters but out side the waters.

If the fish catches decline as a result of Seismic related activities, the fishers can be given loans to enable them initiate other businesses to engage in like agriculture, poultry and livestock farming.

The effect on the people can be withstood after all some people work in factories that produce a lot of noise and vibrations but they are still alive.

7.0 Conclusions and Recommendations

Generally most fishers were sure that the seismic activities would lead to a decline in fish catches and stocks which would affect their livelihoods negatively. Fish would either die or migrate to other areas where the effects of the seismic could not felt.

All the beaches on Lake Albert visited are in a gazetted national park where there was no cultivation allowed and therefore fishing and fishery related activities were the main source of livelihoods. This should be taken note of if the seismic is to reduce catches and stocks by considering fishers' recommendations in the main findings.

Low catches would lead to among others low fish intake especially on the part of fishers and other people around the lake, dwindling of peoples' standards of living, loss of revenues to government among others. Possible measures should therefore be devised to address such losses and the others in the main findings.

Lessons drawn from other seismic surveys can be used to tackle the likely negative impacts that are likely to yield from the one supposed to be carried out on Lake Edward.

Annex 1

Guiding questions in the survey

1. Have you heard of any information regarding the availability of oil in and around this lake Edward and the proposed seismic activities that are supposed to be carried out to confirm the possibility of availability of this oil? If so, from who?
2. What are your expectations and worries if a seismic survey is to be carried out? Refer to fish stocks and catches, fish marketing, district revenues, livelihoods of fishers, water, etc
3. What do you think can be done to positively deal with such worries mentioned in 2 above?
4. Any other relevant information regarding Seismic survey impact on fisheries issues that you may feel is of interest to you.

Appendix 2

List of all people consulted at different landing sites during the survey

Kazinga beach FGD members

1. Kasirye Isaac
2. Christopher Magara
3. Sembatya Dauda
4. Nasuuna Jane
5. Seruwaji Godfrey
6. Bagambana Muzawalu
7. Muitebi Deo
8. Kawoya Kagimu
9. Mulimbezi John
10. Magambo Ali
11. Nagita Alice
12. Nakayemba Sypha

Katwe Landing site FGD members

1. Hawa Kisoro- boat owner
2. Tumuhirwe Rascal- Crew
3. Miria Kajoina- Boat owner
4. Musa Muhindo-crew
5. Joseph Manywema- crew
6. Tumusime David-Student but local resident
7. Deni Baluku-Crew
8. Basaliza Ssengedo-crew
9. Baluku Henry- Crew
10. Yeremiya Kisombere- Boat owner.

Kishenyi landing site FGD members

1. Kabyogamu Muzamilu- Baot owner
2. Baguma Vicent- gear maker
3. Mukairina Bakebuga- Boat owner
4. Yoanina Baryabaka-Boat owner
5. Kazoka William- Boat owner
6. Maine Patrick- Crew
7. Ssaja Muzamilu-Boat owner
8. Muwanga Vicent- Boat owner
9. Isaac Kabagambe- Fish trader
10. Robert Buhimba- Crew
11. Mugisha George-crew
12. Nyakaisiki Hawa- Fish trader

Rweshama landing site members of the FGD

1. Bernard Gumisiriza- Crew
2. Bucunku Apollo- Net spreading

Local council officials
Zimbe Joseph- LC I Secretary/Data collector Rwenshama
Kiniga Sula-LC II Rwenshama
Kabuye Swale- Chairman LC III Katunguru

BMU officials
Musoke Hamidu-Chairman Kazinga
Kisoro William- Vice Chair BMU Kazinga
Kasunzu Sulaiti- Chirman Katwe
Mayanja Patric- Chairman Kishenyi
Tibirinyebwa Joeph- Data collector Rwenshama
Rubahamya Callist-Vice Chair BMU Rwenshama

TERMS OF REFERENCE (TORs)

The consultant shall provide the following services by investigating:

i. Assess the abundance, distribution and ecology of the various fish species in Edward.
ii. Define the criteria against which, impacts on fish resources will be evaluated;
iii. Describe the conservation status of the fish groups above;
iv. Describe and assess likely impacts on the migratory behavior of the fisheries species in the areas;
v. Assess the abundance, distribution and types of phytoplankton, micro/macro invertebrates in the lake.
vi. Establish baseline water quality parameters in areas of the lake and rivers within the seismic survey area;
vii. Describe clear monitoring indicators and regimes to evaluate implications of the development on the water environment; and
viii. Provide in-put to the preparation of the Environment Management and Monitoring Plan.
ix. Assess the impact of the proposed seismic survey activities on the fish ecology, aquatic invertebrates and the general aquatic ecosystem.
x. Assess the impact of the proposed seismic survey on the social economic issues related to the fishing business in and around Lake Edward.
xi. Hold meetings with relevant stakeholders including fishing communities around Lake Edward and document their responses. Document names of all stakeholders consulted including issues raised by them (quoted verbatim).
xii. Map all points, zones and places studied including trading centers, landing sites, island and other sensitive ecosystems or points during the assessment and produce a map locating them.
xiii. Analyze the impacts of the proposed seismic survey on all the parameters studied (biophysical, social-cultural and economic environment) impacts on the aquatic ecosystem and the areas surrounding the lake.
xiv. Suggest appropriate mitigation measures that would minimize the negative impacts and enhance the positive impacts.
xv. Produce a softcopy and hard copy report of detailed findings by 20th of January 2008 to the Managing Director of OPEP Consult Ltd

Appendix 4.
NaFFIRI scientists participating in Study

Name	Qualification	Rank	Specialization
Dr. J. S. Balirwa	BSc, MSc, PhD	Director	Aquatic ecologist
Dr. Dismas Mbabazi	BSc.(Educ), MSc, PhD	Senior Research Officer	Fishery biologist/ecologist
Dr. Levi Muhoozi	BSc, Dip. (Educ), MSc, PhD	Senior Research Officer	Fish stock assessment
Dr. Fred Wanda	BSc, MSc, PhD	Senior Research Officer	Limnologist/Water quality
Dr. Lucas Ndawula	BSc, MSc, PhD	Senior Research Officer	Limnologist/ invertebrates
Mr. Anthony Taabu Munyaho	BSc, MSc	Research Officer	Fishery biologist/ecologist